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A PRELIMINARY STUDY OF RADIONUCLIDE DISTRIBUTIONS IN THE UPLAND VEGETATION OF NORTHERN SASKATCHEWAN

by

J.W. Sheard
Department of Biology
University of Saskatchewan
Saskatoon, Saskatchewan S7N 0W0

A joint project with the
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SUMMARY

Vegetation samples were collected in four localities for a total of ten vascular and non-vascular species and soil, with replication. The 111 samples were analyzed for Pb^{210}, Po^{210}, Ra^{226}, uranium and 22 non-radioactive elements. Significant differences were found between localities for many species for each of the radionuclides. Significant differences over all localities were also found between species and especially groups of species (trees, shrubs, lichens and moss). Average transfer ratios and enrichment factors were calculated for each species at each locality. The transfer ratios were found to be of little value because they were based on absolute levels of radionuclides in the soil rather than levels actually available to the plants.

Levels of accumulation of each radionuclide are amongst the highest reported for any region of the world. Pb^{210} and Po^{210} are decay products of the radioactive gas radon (Rn^{222}) and are distributed in the atmosphere as well as the soil. Their highest level of accumulation occurs in the lichen and moss species, plants which have a very large surface area for trapping airborne particulates. In contrast, Ra^{226} and uranium precede Rn^{222} in the radioactive decay series and in undisturbed forest environments would not be expected to enter the atmosphere as dust in large quantities. Both are soluble and potentially available for root uptake by vascular plants.

Results show a higher accumulation of Ra^{226} in shrubs than trees, while the reverse is marginally the case for uranium. The shrubs have

the highest levels of accumulation of Ra^{226} while the lichens and moss accumulate uranium to levels one order larger than the vascular plants. Since lichens and mosses are poikilohydric plants lacking roots it is unlikely that these extraordinary levels of uranium accumulation are the result of uptake from soil solution. The enrichment factors suggest that Ra^{226} levels can be explained by deposition of soil particles but another source of accumulation is indicated for uranium.

A possible source of uranium for the non-vascular plants is the vascular plant biomass, particularly tree species because of their dominance in the ecosystem under study. Canopy leaching, stem flow, litterfall and excretion from conifers are possible transfer mechanisms between trees and the ground carpet of lichens and moss. The first three mechanisms will probably be more important for moss, which grows in the relative mesic environment below spruce trees, than for lichens which occur most abundantly in the xeric environment between widely spaced trees. It is hypothesized that the excretion of wax particles from the surface of conifer needles is the primary source of uranium for the lichens, their longlevity being responsible for the high levels observed.

Since lichens and mosses dominate the ground flora of most unburned, upland woodlands in northern Saskatchewan they form an important resevoir for Pb^{210}, Po^{210} and uranium. There is potential for the transfer of these radionuclides through the lichen-caribou food chain to man, of uranium through spruce needles to spruce grouse and of Ra^{226} through shrubs to moose and bear.

INTRODUCTION

"The strangest paradox of radiation protection is that the least attention is paid to the strongest sources of human exposure.... It is no exaggeration to say that public and professional interest in natural and artificial radiation is inversely proportional to the radiation dose received from them" (O'Riordan 1983). A very important and, to date, poorly researched source of exposure is foodchain transfer of naturally occurring radionuclides (Figure 1). In Canada there is a growing awareness of the need for research on background radiation in the biotic environment (Shemilt 1983).

An important source of natural radiation is the decay series of uranium-238, (U^{238}, half-life 45×10^9 years) the products of which include radium-226 (Ra^{226}, half-life 1622 years), the gas radon-222 (Rn^{222}, half-life 3.8 days), lead-210 (Pb^{210}, half-life 22 years) and polonium-210 (Po^{210}, half-life 138 days). The Ra^{226}-Po^{210} chain is an important source of man's background radiation burden (Blanchard 1967) and the order of radiotoxicity for the series is $Pb^{210} > Ra^{226} > Po^{210}$ (ICRP 1979). Since Pb^{210} and Po^{210} are the disintegration products of radon gas they are distributed in the atmosphere and return to earth primarily in rainout processes. Experimental work with crop plants has shown that the main source of Pb^{210} is from atmospheric fallout since forage crops with their high surface area, relative to vegetables and grain, have the highest air-plant transfer coefficients (Francis et al. 1968, McDowell-Boyer et al. 1979). Uranium and radium^{226}, in contrast, would be expected to be taken up from the soil

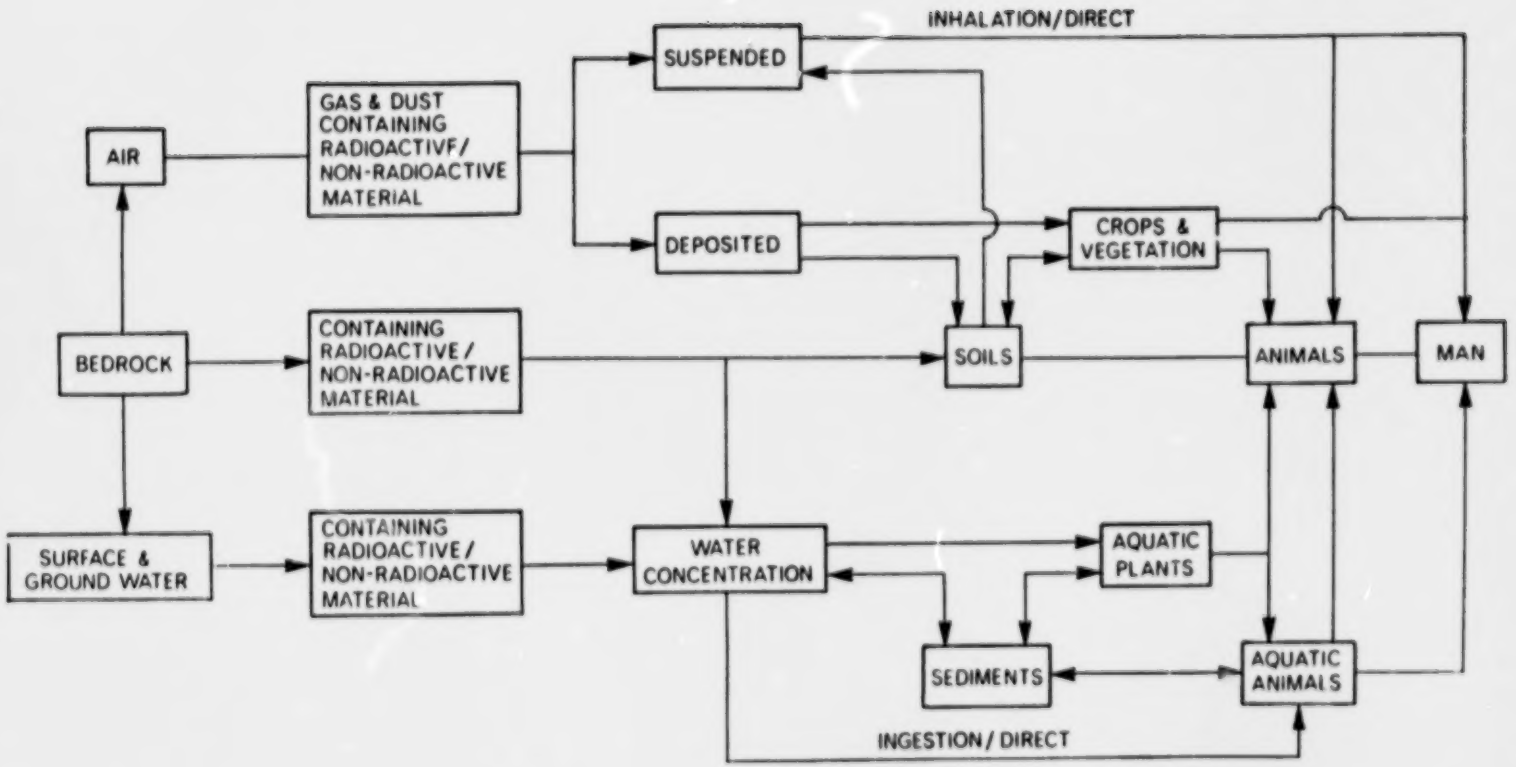

Figure 1. Flow chart for exposure and accumulation pathways of natural radionuclides for biota.

(Cannon 1952, Sheppard 1980) and uranium is sometimes accumulated in impressive amounts (Dunn 1983a). However, around worked deposits uranium is reported to be distributed as particulates in blowing dust up to 22 km downwind (Beckett et al. 1982).

The upland vegetation of northern Saskatchewan consists of conifer forests which if they remain undisturbed by fire, may develop into open lichen woodlands (Black and Bliss 1980, Carroll and Bliss 1982, Rowe 1984). The tree species, Picea mariana and Pinus banksiana, together with the vascular plants of the shrub layer can be expected to predominantly take up uranium and Ra^{226} through their root systems while the lichens and mosses, which lack roots and well developed internal transport mechanisms, might be expected to accumulate relatively large amounts of Pb^{210} and Po^{210} from the atmosphere (Boileau et al. 1982, Folkeson 1979). This effect may be further enhanced in the reindeer lichens of the genus Cladina, which in mature forest stands form the predominant ground cover, by the lack a cortex and consequent extremely rough surface. There have been few studies designed to compare the uptake of natural radionuclides by different plant groups.

Such studies are required because different plant groups form the base trophic level in different food chains leading to man. Reindeer lichens are the major winter food source for caribou, spruce needles are the prime food of spruce grouse and many shrubs are browsed by moose and bear. Each of these animals is utilized by northern residents, indeed northern Saskatchewan has the distinction of being an area where many people depend on wildlife resources for their physical and economic well being (Knoll 1980). Some northern

residents in Canada and Finland with a high or moderate caribou/reindeer diet may show Po^{210} levels up to ×80 (average ×35) as high as other residents with typical southern diets (Hill 1966, Kauranen and Miettinen 1969). Phenomena which might cause radionuclide concentrations to move above these higher background levels are therefore a potential source of concern. One such phenomenon is the uranium mining industry in northern Saskatchewan.

It must be emphasized that there is currently no evidence that the populace of northern Saskatchewan is at risk, or that there is any other environmental impact due to enhanced radiation levels. Nevertheless, segments of the population fear radiation damage. Environmental damage can only be assessed from a knowledge of background radiation levels and such existing information is both sparse and poorly quantified. In February 1983 the Saskatchewan Health Research Board received a proposal for a two year study of radionuclide distributions in the vegetation of natural and perturbed terrestrial ecosystems in northern Saskatchewan. This study would serve to identify plant species at the base of food chains through which radionuclides and possibly co-carcinogens (SENES 1983) might be transmitted to man. Funds were awarded for a one year preliminary study which is now reported.

OBJECTIVES

The primary objective of the present study was to develop a sampling method which would allow detection of differences in background radiation levels between localities and radionuclide accumulation levels between plant species in northern Saskatchewan. This suggested a sampling design with the following specific

objectives:

1. A comparison of background radiation levels between the uranium bearing region of the Athabasca basin and that of the southern part of the Shield.
2. An estimate of variation between localities and regions sampled.
3. An estimate of variation between species and groups of species widely distributed in northern Saskatchewan.
4. A comparison of the variation of radionuclides with that of other elements.

MATERIALS AND METHODS

Study Area

The study area is part of the Northern Boreal Ecoregion, the two northern localities belonging to the Athabasca South Ecodistrict and the southern localities to the Northern Coniferous Ecodistrict (SPRR 1983). The region is characterized as being humid and cold, the mean daily January temperature is ca -24.0°C and the corresponding July temperature is ca 16.5°C. The annual percipitation is about 400 mm.

The Athabasca South Ecodistrict is a drift plane with prominent eskers and drumlins (also sand dunes to the west of the study localities), and regosolic soils at the study sites. Due to the cold climate and nutritionally poor and well drained soils, jack pine (*Pinus banksiana*) stands characterize the upland forests. These communites have an understory dominated by caribou lichens (primarily *Cladina mitis*) and scattered Canada blueberry (*Vaccinium myrtilloides*). Where soil moisture is more abundant, spruce (*Picea mariana*), feather moss (primarily *Pleurozium schreberi*) and labrador tea (*Ledum groenlandium*) are found.

The North Coniferous Ecodistrict has an irregular, bedrock controlled topography. At the study sites, soils were poorly developed and shallow over bedrock, with a species compliment very similar to that of the previous ecodistrict to the north.

Vegetation and soil sampling

Since one study objective was to compare radionuclide uptake in plants between a uranium rich region of the Athabasca Basin and a southern part of the Shield and also to obtain a first estimate of variation within these regions, four localities were selected, two close to Wollaston Lake and two near the Churchill River. The choice of localities was dictated by accessability (road) and a broad selection of species (trees, shrubs, lichens and mosses) in sufficient quantities for collection. Although accessability was a criterion it was also important that the collection sites not be contaminated by road dust. At each of the localities three replicate collection sites were found for which there were no visual differences in community structure. The four localities were as follows:

1. Hidden Bay, Wollaston Lake Region, 58° 07'N 103° 46'E. North of access road to Wollaston Lake Lodge. Lichen woodland on north side of esker. Collection sites 500 m from road.
2. Collins Creek, Wollaston Lake Region, 58° 11'N 103° 51E. South of road to Midwest Lake, adjacent to east shore Kewen Lake. Open spruce woodland over glacial till. Collection sites 500 m from road.
3. 'Birch Hill', Churchill River Region, 55° 43'N 104° 42'E. East of HWY 102, 8.5 km north of Otter rapids. Rock outcrop with scattered jack pine, spruce, paper birch, and open ground cover.

Collection sites regularly spaced 250-300 m from road.

4. Otter Rapids, Churchill River Region, 55° 40'N 104° 43'E. East of HWY 102, 3 km north of Otter Rapids. Rock outcrop with scattered spruce, paper birch and open ground cover. Collection sites regularly spaced 400-600 m from road.

Another objective was to study the range of variation between plant species and species groups. Widely distributed species were selected in the hope that they would be found at all localities in sufficient quantities to be collected. A total of ten species were collected although only seven were found at each locality. Two 200 g (dry weight) samples of each species were collected at each site and placed in polythene bags. The seccnd samples were collected solely as back up samples. Tree and shrub twigs were collected with the aide of garden clippers, the lichens and moss species with teflon coated scissors to reduce the risk of metal contamination. All samples were air dried before transportation to the laboratory.

Leaves and twigs were not separated for any of the vascular plants collected. For the two trees, Pinus banksiana and Picea mariana, the terminal approx. 15 cm were collected. For the shrubs Ledum groenlandicum, Vaccinium myrtilloides and Alnus crispa the terminal non-woody twigs were collected. Because of their small size the whole shoots of Vaccinium vitis-idaea were collected with scissors. The lichens were most easily collected in the morning when they were moist. Although time consuming, cutting the living portions away from their base in situ is the only way to avoid contamination by soil particles and other detritus when collecting. This also applies to mosses. The lichens Cladina rangiferina, C. mitis and C. stellaris

and the moss Pleurozium schreberi were each sampled when present. The samples were first cleaned of detritus (leaves, conifer needles, twigs, etc.) while air drying and again more carefully in the laboratory. This task was especially tedious for the moss samples.

Soil samples were also taken at each replicate site. At the two northern localities soil pits were dug, surface humus removed and a vertical 15 cm section of soil sampled. Surface humus was similarly removed at the two southern sites and soil samples taken from the surface of the bedrock. In no case was there a well developed soil profile.

Chemical Analysis

Vegetation samples for Pb^{210}, Po^{210} and uranium determination were charred then ashed at 500°C prior to analysis. Samples for Po^{210} determination were not ashed. The analytical techniques employed in the SRC analytical laboratory are briefly described below, full details may be found in Smithson (1979).

The direct determination of Pb^{210} is difficult due to the low energy of its beta-emission. Consequently, it is necessary to determine Pb^{210} indirectly through its high energy emitting daughter Bi^{210}. In this procedure, Bi^{210} is isolated by solvent extraction and precipitated as bismuth oxychloride for beta-counting. From the determined Bi^{210} concentration and the degree of equilibrium existing between parent and daughter it is possible to calculate the Pb^{210} content.

Po^{210} is preferentially separated from HCl solution by spontaneous deposition on silver metal. The prepared silver disc is alpha counted and compared to similarly prepared standards to determine the amount

of Po^{210} present. Polonium may, however, be adsorbed on various surfaces during sample preparation. Such losses of polonium are determined by adding Po^{208} as a tracer at the beginning of the procedure. Po^{208} is also an alpha emitter and can be determined simultaneously with Po^{210}, the recorded Po^{208} loss being used to adjust the Po^{210} estimate for the sample.

Ra^{226} is determined by barium sulphate precipitation followed by alpha counting. Radium is removed from the extraction solution by co-precipitation with lead sulphate. The lead sulphate is then removed in alkaline EDTA, barium carrier added and barium sulphate preferentially precipitated by lowering the pH to 4.5. Radium coprecipitates with the barium sulphate and is then redissolved and reprecipitated to remove traces of other radionuclides before counting on a zinc sulphide - Mylar disc. The method is not specific for Ra^{226} and other alpha-emitting radium isotopes (Ra^{224} and Ra^{223}) must be corrected for by differential decay analysis.

Uranium is determined fluorimetrically (HASL 1972). Other details of the determination methods are given in Table 1.

For the analysis of 23 other elements the air dried samples were charred, ashed and digested in a solution of HNO_3 and $HClO_4$. This solution was than subjected to inductively coupled plasma spectrometry (ICP) (Fassel & Kniseley 1974). Detection limits for the elements analyzed are as follows: Ag, Ba, Be, Cd, Co, Cu, Fe, Mu, Ni, Ti, Zn $<$0.2 ug/g; Al, Mo, Pb, W $<$1.0 ug/g; B, Ca, Mg, V $<$2.0 ug/g; K, Na, P $<$10.0 ug/g ash weights. Soil samples were treated in the same way as vegetation samples throughout.

Table 1. Summary of sample preparation and analytical procedures for radionuclide determinations.

Radionuclide	Sample Preparation	Analytical Method	Detection Limit	Precision
210-Pb	Ashed at 500°C followed by nitric acid dissolution (vegetation), aqua-regia/perchloric acid dissolution (soil)	210-Bi activity in BiOCl precipitate	0.02 Bq	± 10-100% from 0.02 to 0.4 Bq ± 4% above 0.4 Bq
226-Ra	Ashed at 500°C followed by nitric acid dissolution (vegetation), pyrosulfate fusion (soil)	Precipitation as $Ba(Ra)SO_4$ and alpha spectrometry	0.005 Bq	± 10-100% from 0.005 to 0.2 Bq ± 10% above 0.2 B
210-Po	Nitric-perchloric acid dissolution (vegetation), aqua-regia/perchloric acid dissolution (soil)	Deposition on silver & alpha spectrometry	0.005 Bq	± 10-100% from 0.005 to 0.4 Bq ± 5% above 0.4 Bq
Total U	Ashed at 500°C (vegetation), aqua-regia/perchloric acid dissolution (soil)	Fluorometric	0.1 g	± 5%

Statistical analyses

Univariate analyses are used on the radionuclide data to test the hypothesis that for a given radionuclide the data, with respect to both the collection sites and the species, are not distributed at random. The method used is analysis of variance (ANOVA), lucidly described by Sokal and Rohlf (1981), in two models; one-way nested ANOVA and factorial (two-way) nested ANOVA. The one-way nested model is used to determine if there are significant differences of radionuclide accumulation between regions and between localities within regions, for each species separately. The same model might have been used to test for differences between species for each region and/or locality. In the context of known biological variation, however, this test seemed too trivial to apply. On the other hand, it was important to determine if there were differences between species groups and species within species groups over all localities, and between regions and localities within regions over all species. Both these questions could be answered by the application of two-way nested ANOVA. The source of any significant differences may be determined by the application of Student-Newman-Keuls (SNK) multiple range tests following ANOVA. These univariate procedures are used routinely in biological research. One complication was that the number of observations for all treatments were not always equal because of incomplete data; not all species were present at all collecting sites. It was possible to analyze such data using the general linear model ANOVA (GLM, Type III) which is a part of the SAS (1982) program package.

A similar univariate approach could have been taken with each of the 20 elements analyzed but this would not necessarily have lead to a better understanding of co-variation between the elements and radionuclides or between the species and their localities although numerous, highly significant differences would undoubtedly have been found. There is currently an increased recognition that a series of univariate tests is as inappropriate for a multivariate problem, as is a series of t-tests for a univariate multi-group problem (Green 1980).

The multivariate method chosen to analyze the study data was principal components analysis (PCA). Among multivariate techniques this method makes the fewest statistical assumptions and has proven to be robust in numerous ecological applications (Orloci 1978, Gauch 1982, Pielou 1984). The method first involves the calculation of a correlation matrix between all possible pairs of variables (elements in our study). If groups of correlated variables are found then it becomes possible to replace these by new, synthetic attributes which carry the same information as the variables from which they are derived. These synthetic attributes are the principal components resulting from the analysis. As many components are extracted as there are attributes, but if the analysis is successful most of the information in the original data matrix will be contained in the first few components. The dimensionality of the data matrix is thereby reduced and its structure simplified. The correlation of the variables with each component is described by a set of transformation coefficients (loadings).

The sum of squares of the transformation coefficients for the individual components is an expression of the relative amount of

variance that each component accounts for in the correlation matrix and hence the original data matrix. The sum of squares is called the eigenvalue (or latent root) and is conveniently expressed as a percentage of the total variance (trace) for all components. The trace is equal to the sum of the elements in the principal diagonal of the matrix from which the eigenvalues are extracted and, since these are unities (self correlations) in a correlation matrix, the trace equals the number of variables in this special case. This helps explain why the eigenvalues (and their components) represent a redistribution of variances in the correlation matrix and why, as a rule of thumb, interest is usually focused upon those components with eigenvalues > 1.0. The last components extracted represent the error variances of the variables which are of no interest. There is a grey area between these components and those with eigenvalues of < 1.0 which may or may not contain useful information.

Scores for the observations (plant species or soils) on the principal components may also be obtained by multiplication of the matrix of transformation coefficients by the standardized data matrix. Since there are 111 observations this information is more easily transmitted in graphical rather than tabular form by using the observation scores on pairs of components as co-ordinates in the construction of ordination diagrams. Structure in the data is identified by reference to both the table of transformation coefficients for the variables and the scores for the observations on the axes (components) of the ordination diagrams. The full sequence of matrix operations involved in PCA is neatly summarized by Williamson (1972, Fig. 16.3). Gittins (1969) gives a more thorough

but primarily unstatistical discussion of the application of PCA in plant ecology.

RESULTS

Samples for the study were collected by localities (2) within regions (2) and by species (11, including soil samples as a species) within species groups (5, again including soil), with three replicates per locality. The basic data matrix should therefore comprise (4 x 11 x 3) 132 samples with measurements for 26 elements. However, not all species were present at all localities so that the total number of samples was 111. This data matrix is listed in Appendix I.

The percentage of ash in oven dry vegetation samples varies between species as shown in Table 2. Shrubs have the highest ash content and lichens the lowest. Note that in the following text the results are presented on a dry weight basis since the ultimate interest in the data is in the transfer of radionuclides in the food chain. As will be seen from Table 2 approximate multiplication factors for correcting ash weight to dry weight is x0.025 for the trees, shrubs and moss and x0.01 for the lichens. There is no evidence from the values for the non-vascular species that any locality has received an excess of particulates as road dust or in any other form.

The importance of careful and standardized collecting procedures cannot be overemphasized. In this study leaves and twigs of trees and shrubs were not separated but their combined percent ash content is comparable with average value of these organs calculated from Sheppard and Thibault (1984). However, the values for lichens and bryophytes

Table 2. Percentage ash in oven dry vegetation samples summarized by species and locality. Means with the same letters are not significantly different (SNK test).

Species	Wollaston Lake		Churchill River		Species		Group	
	Hidden Bay	Collins Creek	Birch Hills	Otter Rapids	SNK Test	Mean	SNK Test	Mean
P. banksiana	2.338		1.948		D	2.143		Trees
P. mariana	2.589	2.260	1.977	2.319	D	2.286	C	2.238
V. myrtilloides	3.128	2.878	3.312	3.078	A	3.099		
L. groenlandicum	2.965	2.792	2.878	2.503	BC	2.785		Shrubs
A. crispa		3.148	2.855	3.058	AB	3.021	A	2.913
V. vitis-idaea	2.686	3.130	2.898	2.381	BC	2.774		
C. rangiferina	0.974	0.688	0.688	1.006	F	0.834		Lichens
C. mitis			1.257	1.099	E	1.178	D	0.982
C. stellaris	1.139	1.024			EF	1.081		
P. schreberi	2.715	2.189	3.105	2.630	C	2.660	B	2.660

are very different, those of Sheppard and Thibault being higher by a factor of two. In the present study care was taken to collect only the upper, living portion of the thalli. In this way possible contamination by soil particles is avoided and decomposed basal parts which have higher ash contents are excluded. This latter fact is demonstrated by Sheppard and Thibault who show substantially higher ash contents for the partially decomposed parts of moss thalli. It is also essential to remove other detritus from the living parts collected. The noted differences in ash content of the non-vascular plants in the two studies is most probably due to difference in collection technique.

Exploratory data analysis

Parametric statistical analyses theoretically require that data be normally distributed. Experience suggests that many statistical techniques are, in fact, relatively robust to violations of this requirement provided that departures from normality are not large. In practice, however, departure from normality is rarely tested and gross violations of the requirement are often incurred with unknown results.

Table 3 gives the skewness and kurtosis of each variable. Logarithmic transformation ($\log_{10}$) improved the skewness (normality) of 18 of the variables at the cost of a minor increase in kurtosis of seven of them. Table 4 allows comparison of the summary statistics for the transformed data with those of the original data in Table 3.

Two elements present in Table 3 are missing from Table 4. Barium was dropped from further analysis because of uncontrolled variation in the chemical analyses. Tungsten was dropped because the majority of

Table 3. Summary statistics for vegetation and soil data.

Variable	Minimum Value	Maximum Value	Mean	Skewness	Kurtosis
Pb^{210}	0.010	0.090	0.199	0.994	0.029
Po^{210}	0.010	0.450	0.136	0.941	-0.539
Ra^{226}	0.020	4.000	0.446	4.144	20.766
Uranium	0.200	353.000	43.241	2.356	4.159
Boron	5.000	550.000	172.811	0.598	-0.889
Phosphorus	100.000	68000.000	36045.946	-0.884	0.728
Silver	0.200	20.000	2.357	3.265	15.009
Aluminum	1500.000	36000.000	11626.126	0.958	-0.393
Barium	18.000	4100.000	387.784	4.339	25.826
Beryllium	0.200	7.100	1.978	1.300	0.536
Calcium	0.000	260000.000	118864.865	-0.148	-1.434
Cadmium	0.200	31.000	6.271	1.483	1.303
Cobalt	0.500	54.000	6.167	3.280	13.880
Chromium	5.200	280.000	28.178	5.513	44.153
Copper	1.000	340.000	117.514	0.376	1.016
Iron	500.000	24000.000	6453.153	1.093	-0.146
Potassium	0.000	201000.000	100405.405	-0.108	-1.224
Magnesium	200.000	70000.000	34375.676	-0.357	-0.433
Manganese	0.000	130000.000	16119.820	3.109	13.829
Sodium	90.000	6200.000	1534.324	1.158	0.186
Nickel	2.000	190.000	45.396	1.484	2.815
Lead	1.000	260.000	33.153	2.087	3.797
Titanium	1.000	1100.000	239.793	1.495	1.152
Vanadium	5.000	95.000	39.649	0.851	-0.582
Tungsten	1.000	9.000	2.423	1.598	3.637
Zinc	0.000	3600.000	1035.946	0.913	1.555

Units of measurement are Pb^{210}, Po^{210} Bq/g dry wt.
Ra^{226} Bq/g ash wt.
remainder ug/g ash wt.

Table 4. Summary statistics for transformed vegetation and soil data. Asterisked (*) elements are $\log_{10}$ transformed.

Variable	Mean	Standard Deviation	Skewness	Kurtosis
*Pb^{210}	0.074	0.067	0.810	-0.677
*Po^{210}	0.051	0.051	0.847	-0.772
*Ra^{226}	0.139	0.123	2.305	7.333
*Uranium	0.858	0.754	1.096	0.077
*Boron	1.929	0.624	-0.518	-1.054
Phosphorus	36045.946	15974.484	-0.884	0.728
*Silver	0.408	0.300	0.725	-0.256
*Aluminum	3.892	0.402	0.064	-1.220
*Beryllium	0.400	0.245	0.628	-0.784
Calcium	118864.865	76639.710	-0.148	-1.434
*Cadmium	0.618	0.453	0.549	-1.266
*Cobalt	0.679	0.370	0.598	-0.356
*Chromium	1.343	0.308	0.535	-0.123
Copper	117.514	61.970	0.376	1.016
*Iron	3.603	0.433	0.198	-1.097
Potassium	100405.405	61366.319	-0.108	-1.224
Magnesium	34375.676	17396.281	-0.357	-0.433
*Manganese	3.667	1.183	-2.155	4.268
*Sodium	2.987	0.471	-0.128	-0.643
*Nickel	1.545	0.353	-0.631	0.388
*Lead	0.951	0.694	0.817	-0.936
*Titanium	1.990	0.664	-0.391	-0.181
*Vanadium	1.526	0.276	-0.156	-0.280
Zinc	1035.946	702.412	0.913	1.555

Units of measurement are Pb^{210}, Po^{210} Bq/g dry wt.
Ra^{226} Bq/g ash wt.
remainder ug/g ash wt.

observations were less than the lower limit of detection. Other observations below the detection limit were included in the statistical analysis.

Univariate analyses

1. Analysis of variance (ANOVA)

Analyses of variance were carried out on the transformed data for each radionuclide for each species and soil to determine if differences in accumulation occur between regions or between localities within regions. These results are summarized for Pb^{210} in Table 5. The soil and four of the eight species for which comparisons are possible show significant differences between the Wollaston Lake and Churchill River regions. It should be noted that the single comparable lichen species and the moss do not show significant differences between the regions. This evidence therefore suggests that Pb^{210} is uniformly distributed in the atmosphere and that the differences between regions for the vascular plants may be due to uptake from the soil where there are also significant differences. Contrary to what might have been expected, the level of Pb^{210} in the soil is greatest in the Churchill River region, whereas the highest accumulation in plants occurs in the Wollaston Lake region (Table 6b). Soil Pb^{210} shows significant differences between regions and between localities within regions, this latter being the result of high levels at Otter Rapids in the south. In contrast, the significant differences between localities for three species are due to the high levels in the north, at Collins Creek. One of these species is the lichen, Cladina mitis, the only non-vascular plant to show a significant difference between localities for Pb^{210} (Table 5).

Table 5. Pb^{210} analysis of variance summaries for all species and soil. Analysis design is localities nested within regions. Sum of squares x 10,000.

	Error		Regions			Localities		
Species (No.)	SS	df	SS	df	F	SS	df	F
P. banksiana (2)	0.805	4	0.115	1	0.57 n.s.		-	
P. mariana (6)	3.270	8	3.213	1	7.86 *	6.260	2	7.66 *
V. myrtilloides (1)	12.242	8	64.601	1	42.22 ***	1.464	2	4.79 *
L. groenlandicum (3)	1.886	8	2.353	1	9.98 *	0.245	2	0.52 n.s.
A. crispa (4)	3.597	6	31.190	1	52.03 ***	0.030	1	0.05 n.s.
V. vitis-idaea (5)	10.525	8	0.367	1	0.28 n.s.	3.147	2	1.20 n.s.
C. rangiferina (7)	13.811	4		-		1.726	1	0.50 n.s.
C. mitis (8)	3.339	4		-		14.806	1	17.74 **
C. stellaris (0)	18.343	8	2.996	1	1.31 n.s.	3.101	2	0.68 n.s.
P. schreberi (9)	63.328	8	0.194	1	0.02 n.s.	65.644	2	4.15 n.s.
Soil (11)	3.735	8	43.704	1	93.62 ***	19.914	2	21.33 ***

n.s. non-significant, * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

Table 6a. Pb^{210} two-way analysis of variance, species nested within species groups and localities nested within regions. Sum of squares x 10,000.

Source	df	Sum of squares	F
Model	17	4716.46	96.25 ***
Regions	1	0.08	0.03 n.s.
Localities within Regions	2	46.65	8.09 ***
Group	4	3971.09	344.40 ***
Species within Groups	6	179.96	10.41 ***
Regions x Groups	4	79.55	6.90 ***
Error	93	268.08	

n.s. non-significant * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

Table 6b. Pb^{210} cell means (Bq/g dry wt.) for model and Student-Newman-Keuls range text for main effects. Means with the same letter are not significantly different. Group and species codes are listed in Table 5.

		Wollaston Lake		Churchill River		Species		Group	
		Hidden	Collins	Birch	Otter	SNK		SNK	
Group	Species	Bay	Creek	Hills	Rapids	Test	mean	Test	mean
1	2	0.040		0.047		E	0.043		
1	6	0.030	0.077	0.037	0.020	E	0.041	D	0.042
2	1	0.180	0.267	0.090	0.107	D	0.161		
2	3	0.067	0.077	0.050	0.050	E	0.061		
2	4		0.130	0.030	0.033	E	0.064	C	0.090
2	5	0.077	0.047	0.080	0.060	E	0.066		
3	0	0.467	0.500	0.467	0.433	B	0.467		
3	7			0.367	0.333	C	0.350	B	0.417
3	8	0.333	0.433			C	0.383		
4	9	0.433	0.667	0.567	0.500	A	0.542	A	0.542
5	11	0.023	0.020	0.070	0.163	E	0.069	CD	0.069
Locality	mean	0.183	0.246	0.180	0.189				
	SNK	B	A	B	B				
Region	mean	0.215		0.184		Grand mean		0.199	
	SNK	A		B					

The higher values for soil Pb^{210} in the south than in the northern uranium bearing region may seem surprising but is probably due to the immature soils in the southern localities which are limited to fissures and depressions in the bedrock. In contrast, the northern soils have developed on glacial overburden (Dunn 1983), imported from regions to the northeast of the Athabasca Basin and therefore well removed from bedrock. It must be concluded that much of the Pb^{210} content of the immature soils is not available for uptake by plants.

Differences between species groups and species within groups were tested using two-way (factorial) analysis of variance against localities within regions. Table 6a summarizes these results. All effects tested, except that between regions, are significantly different. The SNK tests reported in Table 6b indicate where these differences lie, but are less conservative and sometimes show significant differences when 2-way ANOVA does not, notably between regions in this instance. The species groups are all significantly different from each other but neither the trees nor shrubs are significantly different from the level of Pb^{210} in soil. Most species within the species groups are not significantly different from each other with the exception of Vaccinium myrtilloides (1) in the shrubs and Cladina stellaris (0) in the lichens, both of which accumulate significantly larger quantities than other members of their respective groups.

The cell means for species within localities in Table 6b summarize the distribution of Pb^{210} at a glance. It may be noted that all species except Vaccinium vitis-idaea (5) have their highest accumulation levels at Collins Creek. Although the effect is not

significant (Table 5) this species has its lowest accumulation at Collins Creek. The chemical analyses were repeated and the low levels for Vaccinium vitis-idaea at this locality confirmed.

Po^{210} is derived from Pb^{210} and although shorter lived might be expected to behave in much the same way as Pb^{210}. The results of Tables 7 and 8 show this to be the case except that only two species show significant differences between regions (both shrubs) and none between localities within regions (Table 7). Table 8b indicates that Po^{210} levels are consistently lower than Pb^{210} as would be expected but not in excess of 50%. These lower levels and the shorter half life would account for a greater error variance and hence fewer significant differences.

The species groups were significantly different from each other with the exception of the trees and shrubs (Table 8b). The two Vaccinium species show the same anomalous patterns of accumulation for Po^{210} as for Pb^{210}. The three lichen species are significantly different from each other but since Cladina rangiferina (7) and C. mitis (8) do not occur together this can be attributed to regional differences. In contrast to Pb^{210}, C. stellaris (0) is not significantly different from the moss, Pleurozium schreberi (9).

Only Vaccinium vitis-idaea (5) and Cladina stellaris (0) show significant differences in accumulation of Ra^{226} between the regions and four of nine possible species show significant differences between localities within regions (Table 9). There are, however, no significant overall differences between species or species groups but the shrubs, excluding Alnus crispa (4), have relatively high accumulations (Table 10b).

Table 7. Po^{210} analysis of variance summaries for all species and soil. Analysis design is localities nested within regions. Sum of squares x 10,000.

	Error		Regions			Localities		
Species (No.)	SS	df	SS	df	F	SS	df	F
P. banksiana (2)	1.174	4	0.031	1	0.11 n.s.		-	
P. mariana (6)	2.122	8	1.200	1	4.52 n.s.	2.133	2	4.02 n.s.
V. myrtilloides (1)	6.953	8	24.319	1	27.98 ***	2.465	2	1.42 n.s.
L. groenlandicum(3)	1.754	8	0.527	1	2.40 n.s.	0.465	2	1.06 n.s.
A. crispa (4)	0.357	6	5.618	1	94.40 ***	0.000	1	0.00 n.s.
V. vitis-idaea (5)	3.435	8	0.523	1	1.22 n.s.	0.282	2	0.33 n.s.
C. rangiferina (7)	7.127	4		-		9.254	1	5.19 n.s.
C. mitis (8)	7.682	4		-		7.749	1	4.03 n.s.
C. stellaris (0)	38.186	8	3.206	1	0.67 n.s.	3.796	2	0.40 n.s.
P. schreberi (9)	40.142	8	7.316	1	1.46 n.s.	11.218	2	1.12 n.s.
Soil (11)	3.941	8	59.352	1	120.48 ***	30.223	2	30.67 ***

n.s. non-significant, $^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$

Table 8a. Po^{210} two-way analysis of variance, species nested within species groups and localities nested within regions. Sum of squares x 10,000.

Source	df	Sum of squares	F	
Model	17	2618.74	74.87	***
Regions	1	0.05	0.02	*
Localities within regions	2	2.46	1.81	n.s.
Groups	4	2134.32	259.33	***
Species within groups	6	118.01	9.56	***
Regions x Groups	4	79.90	9.71	***
Error	93	191.35		

n.s. non-significant, * $P<0.05$, ** $P<0.01$, *** $P<0.001$

Table 8b. Po^{210} cell means (Bq/g dry wt.) for model and Student-Newman-Keuls range test for main effects. Means with the same letters are not significantly different. Group and species codes are listed in Table 7.

Group	Species	Wollaston Lake		Churchill River		Species		Group	
		Hidden Bay	Collins Creek	Birch Hills	Otter Rapids	SNK Test	mean	SNK Test	mean
1	2	0.033		0.030		E	0.032	D	0.030
1	6	0.023	0.050	0.027	0.017	E	0.029		
2	1	0.113	0.143	0.063	0.050	D	0.093		
2	3	0.030	0.043	0.027	0.027	E	0.032		
2	4		0.057	0.017	0.017	E	0.030	CD	0.051
2	5	0.043	0.033	0.050	0.047	E	0.043		
3	0	0.383	0.333	0.333	0.317	A	0.342		
3	7			0.250	0.180	C	0.215	B	0.291
3	8	0.233	0.300			B	0.267		
4	9	0.350	0.433	0.333	0.350	A	0.367	A	0.367
5	11	0.020	0.020	0.073	0.190	DE	0.076	C	0.076
Locality		0.137	0.157	0.120	0.133				
		AB	A	B	AB				
Region		0.147		0.126		Grand Mean		0.136	
		A		B					

Table 9. Ra^{226} analysis of variance summaries for all species and soil. Analysis design is localities nested within dry regions. Sum of squares x 10,000.

	Error		Regions				Localities			
Species	SS	df	SS	df	F		SS	df	F	
P. banksiana (2)	0.002	4	0.0024	1	5.76	n.s.	-	-	-	
P. mariana (6)	0.359	8	0.183	1	4.08	n.s.	0.287	2	3.20	n.s.
V. myrtilloides(1)	0.428	8	0.191	1	3.57	n.s.	0.579	2	5.41	*
L. groenlandicum (3)	4.928	8	2.144	1	3.48	n.s.	4.926	2	4.00	n.s.
A. crispa (4)	0.068	6	0.006	1	0.51	n.s.	0.074	1	6.52	*
V. vitis-idaea(5)	1.865	8	5.082	1	21.80	**	5.631	2	12.08	*
C. rangiferina (7)	0.016	4	-	-	-	-	0.008	1	1.94	n.s.
C. mitis (8)	0.030	4	-	-	-	-	0.043	1	5.81	n.s.
C. stellaris (0)	0.016	8	0.035	1	17.48	**	0.005	2	1.21	n.s.
P. schreberi (9)	0.126	8	0.000	1	0.01	n.s.	0.159	2	5.06	*
Soil (11)	7.616	8	53.355	1	56.05	***	115.073	2	60.44	***

n.s. non-significant, * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

Table 10a. Ra^{226} two-way analysis of variance, species nested within species groups and localities nested within regions. Sum of squares x 100.

Source	df	Sum of squares	F	
Model	17	261.194	12.29	***
Regions	1	19.011	15.20	***
Localities within Regions	2	30.391	12.15	***
Group	4	163.658	32.72	***
Species within Groups	6	5.400	0.72	n.s.
Regions x Groups	4	41.040	8.20	***
Error	93	116.301		

n.s. non-significant, * $P < 0.01$, ** $P < 0.01$, *** $P < 0.01$

Table 10b. Ra^{226} cell means (Bq/g dry wt.) for model and Student-Newman-Keuls range test for main effects. Means with the same letters are not significantly different. Group and species codes are listed in Table 9.

		Wollaston Lake		Churchill River		Species		Group	
Group	Species	Hidden Bay	Collins Creek	Birch Hills	Otter Rapids	SNK Test	mean	SNK Test	mean
1	2	0.189		0.098		B	0.143		
1	6	0.165	0.164	0.230	1.248	B	0.452	B	0.349
2	1	1.095	2.414	1.471	0.857	B	1.459		
2	3	1.353	1.814	1.454	5.795	B	2.604		
2	4		0.736	0.604	1.119	B	0.820		
2	5	0.519	1.163	1.639	6.243	B	2.391	B	1.885
3	0	0.434	0.438	0.120	0.251	B	0.311		
3	7			0.237	0.401	B	0.319		
3	8	0.563	0.955			B	0.759	B	0.425
4	9	0.592	0.953	0.428	1.093	B	0.767	B	0.767
5	11	0.043	0.063	0.050	0.283	A	0.110	A	0.110
Locality		0.550	0.967	0.633	1.921				
	SNK	B	B	B	A				
Region		0.759		1.243					
	SNK	B		A					
							Grand mean		1.007

The two regions are significantly different overall (Table 10b). Otter Rapids in the Churchill River region has the highest overall Ra^{226} levels, followed by Collins Creek in the Wollaston Lake region. Vaccinium myrtilloides (1) and Cladina stellaris (0) are exceptional in that their highest accumulations occur at Collins Creek in the north, and the lowest level for V. myrtilloides occurs at Otter Rapids in the south.

Results for the analysis of uranium levels for all species across regions and localities are reported in Table 11. All species including soil, show highly significant differences between the two regions. On the other hand only Picea mariana (6) and the moss Pleurozium schreberi (11) show significant differences between localities within regions. The data are further explored by two-way analysis in Table 12. There are significant overall differences between the vascular and non-vascular plants (Table 12b), the levels of uranium in the latter being higher by one order of magnitude. Note that where they co-occur, levels in Pinus banksiana (2) exceed those of Picea mariana and by a factor of about five at Hidden Bay. Amongst the shrubs V. myrtilloides (1) accumulates comparable amounts of uranium to P. banksiana.

There is a very large and significant difference between the Wollaston Lake and Churchill River regions but smaller differences between localities within regions. This contrasts with Ra^{226} where the largest overall differences in accumulation occurred between localities. The results for uranium are comparable to Pb^{210} in that the highest levels in the soil are found in the Churchill River region whereas the highest levels for vegetation are found in the Wollaston

Table 11. Uranium analysis of variance summaries for all species and soil. Analysis design is localities nested within dry regions.

	Error		Regions				Localities			
Species	SS	df	SS	df	F		SS	df	F	
P. banksiana (2)	4.464	4	549.955	1	492.83	***	-	-	-	
P. mariana (6)	11.172	8	132.782	1	95.09	***	18.785	2	6.73	*
V. myrtilloides (1)	10.437	8	1007.597	1	772.30	***	11.554	2	4.43	n.s.
L. groenlandicum (3)	7.838	8	128.244	1	130.89	***	2.430	2	1.24	n.s.
A. crispa (4)	0.505	6	42.577	1	505.84	***	0.009	1	0.11	n.s.
V. vitis-idaea (5)	19.149	8	252.401	1	105.45	***	8.807	2	1.84	n.s.
C. rangiferina (7)	0.115	4	-		-		0.021	1	0.74	n.s.
C. mitis (8)	106.911	4	-	-	-		147.102	1	5.50	n.s.
C. stellaris (0)	1323.154	8	8790.326	1	217.61	***	62.090	2	0.77	n.s.
P. schreberi (9)	92.883	8	9989.586	1	860.40	***	200.443	2	8.63	*
Soil (11)	1301.010	8	5776.866	1	35.52	***	3047.415	2	9.37	**

n.s. non-significant, * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

Table 12a. Uranium two-way analysis of variance, species nested within species groups and localities nested within regions.

Source	df	Sum of squares	F
Model	17	7.183	74.02 ***
Regions	1	0.593	103.96 ***
Localities within Regions	2	0.053	4.62 *
Group	4	3.287	143.95 ***
Species within Groups	6	0.067	1.96 n.s.
Regions x Groups	4	2.085	91.32 ***
Error	93	0.531	

n.s. non-significant, * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

Table 12b. Uranium cell means (uq/q dry wt.) for model and Student-Newman-Keuls range test for main effects. Means with the same letters are not significantly different. Group and species codes are listed in Table 11.

Group	Species	Wollaston Lake Hidden Bay	Wollaston Lake Collins Creek	Churchill River Birch Hills	Churchill River Otter Rapids	Species SNK Test	Species mean	Group SNK Test	Group mean
1	2	56.667		0.769		C	28.718	C	15.578
1	6	12.677	22.147	0.595	0.614	C	9.008		
2	1	51.182	61.106	2.323	2.263	C	29.219		
2	3	19.099	15.658	0.935	0.921	C	9.153		
2	4		12.686	1.235	1.420	C	5.114	C	14.847
2	5	21.932	29.018	1.812	1.111	C	13.468		
3	0	285.429	241.019	2.026	3.388	B	132.966		
3	7			3.612	3.328	C	3.470	B	141.256
3	8	252.243	338.999			A	295.621		
4	9	253.369	360.923	7.294	5.628	B	156.804	B	156.804
5	11	0.900	1.833	3.033	10.267	A	4.008	A	4.008
Locality		105.944	120.377	2.364	3.216				
	SNK	A	A	C	B				
Region		113.160		2.767		Grand mean	56.472		
	SNK	A		B					

Lake region and this without exception. The highest levels in the vegetation, with the exception of Ledum groenlandicum (3) and Cladina stellaris, are found at Collins Creek in the Wollaston Lake region.

Summary tables for the accumulation pattern of other elements studied are given in Appendix II.

2. Radionuclide transfer ratios

The ratio of an element level in a plant to that in the soil in which it is found is known as the transfer ratio from soil to plant (Sheppard 1984). The calculation of this ratio assumes that uptake of the element by the plant is from the soil alone which may be approximately true for some elements and plants but will be in error for airborne elements and plants which effectively trap airborne particulates. Pb^{210}, Po^{210} and lichens and mosses belong to these categories.

The average transfer ratio for Pb^{210} (Table 13) for the Churchill River region is much lower than that for the Wollaston Lake region and reflects the higher values for all radionuclides in the soils of the two southern localities as indicated in Table 6. There are also significant differences between localities within both regions.

The species groups show increasing transfer ratios in the order trees, shrubs, lichens and moss. The high values for the latter two groups are consistent with their being efficient accumulators of airborne particulates. The species have relatively similar values within species groups. Note that the average values for Alnus crispa (4), Cladina rangiferina (7) and C. mitis (8) are weighted by not being equally represented in both regions. Amongst the shrubs, Vaccinium myrtilloides (1) has an average value more than twice that

Table 13. Pb^{210} transfer ratios. Student-Newman-Keuls tests for main effects following two-way analysis of variance. Means with the same letter are not significantly different. Group and species codes are listed in Table 5.

		Wollaston Bay		Churchill River		Species		Groups	
		Hidden	Collins	Birch	Otter	SNK		SNK	
Group	Species	Bay	Creek	Hills	Rapids	Test	Mean	Test	Mean
1	2	1.8	-	0.7	-	1.3	D	1.4	C
1	6	1.3	3.8	0.5	0.1	1.5	D		
2	1	8.2	13.3	1.6	0.7	5.9	C		
2	3	2.9	3.8	0.8	0.3	2.0	C D	3.1	C
2	4	-	6.5	0.5	0.2	2.4	C D		
2	5	3.6	2.3	1.3	0.4	1.9	C D		
3	7	-	-	5.7	2.1	3.9	C D		
3	8	14.7	21.7	-	-	18.2	A	12.6	B
3	0	21.1	25.0	7.6	2.7	14.1	B		
4	9	19.1	33.3	9.2	3.1	16.2	A B	16.2	A
Locality	mean	9.1	13.7	3.1	1.2				
	SNK	B	A	C	D				
Region	mean	11.4		2.2					
	SNK	A		B		Grand mean 6.7			

of any other species. Note that Vaccinium vitis-idaea (5) is the only species having a transfer ratio higher at Hidden Bay than Collins Creek, reflecting its dry weight accumulation of Pb^{210}.

Transfer ratios for Po^{210} (Table 14) are generally slightly lower than those of Pb^{210} but vary in a similar manner as would be expected since it is the relatively short lived daughter of Pb^{210}. In the case of Po^{210}, however, there is no significant difference between localities within regions, or between the lichen and moss species.

There is a smaller variation in Ra^{226} transfer ratios (Table 15) than for Pb^{210} although the values for the Wollaston Lake region remain larger than for the Churchill River region. The largest average transfer ratio is for the shrubs which are significantly different from the other groups.

Uranium transfer ratios show the largest difference between the northern and southern regions for all radionuclides (Table 16). There is also a significant difference between the two localities within the Wollaston Lake region. The vascular plants have transfer ratios one order of magnitude less than the non-vascular species and species within species groups do not differ significantly with the exception of the lichen species that have different distributions. Differences between species are more similar to the results shown by Pb^{210} than Ra^{226}. One inference might be that uranium and Pb^{210} are both being accumulated by airborne particulates but in the case of uranium the source cannot be Rn^{222}.

Appendix III lists the transfer ratios for all elements by locality, region, species and species group.

Table 14. Po^{210} transfer ratios. Student-Newman-Keuls tests for main effects following two-way analysis of variance. Means with the same letter are not significantly different. Group and species codes are listed in Table 5.

		Wollaston Lake		Churchill River		Species		Groups	
		Hidden	Collins	Birch	Otter	SNK		SNK	
Group	Species	Bay	Creek	Hills	Rapids	Test	Mean	Test	Mean
1	2	2.2	-	0.4	-	1.3	B	1.9	B
1	6	1.3	2.5	0.3	1.9	1.1	B		
2	1	7.4	7.2	0.9	0.3	3.9	B		
2	3	1.6	2.2	0.4	0.1	1.1	B	1.1	B
2	4	-	2.8	0.3	0.1	1.1	B		
2	5	3.2	1.6	0.8	0.2	1.5	B		
3	7	-	-	3.9	1.0	2.4	B		
3	8	14.4	15.0	-	-	14.7	A	10.4	A
3	0	25.3	16.6	5.1	1.7	12.2	A		
4	9	21.9	21.7	5.5	1.8	12.7	A	12.7	A
Locality	mean	9.7	8.7	2.0	0.7				
	SNK	A	A	B	B				
Region	mean	9.2		1.4					
	SNK	A		B		Grand mean	5.2		

Table 15. Ra^{226} transfer ratios. Student-Newman-Keuls tests for main effects following two-way analysis of variance. Means with the same letter are not significantly different. Group and species codes are listed in Table 5.

		Wollaston Lake		Churchill River		Species		Groups	
		Hidden	Collins	Birch	Otter	SNK		SNK	
Group	Species	Bay	Creek	Hills	Rapids	Test	Mean	Test	Mean
1	2	0.047		0.026		C	0.037	B	0.042
1	6	0.041	0.027	0.066	0.043	C	0.044		
2	1	0.289	0.396	0.323	0.030	AB	0.260		
2	3	0.390	0.299	0.353	0.199	A	0.310		
2	4	-	0.120	0.148	0.040	C	0.103	A	0.243
2	5	0.145	0.198	0.491	0.219	AB	0.263		
3	0	0.122	0.072	0.034	0.009	C	0.059		
3	7	-	-	0.076	0.014	C	0.045	B	0.079
3	8	0.146	0.157	-	-	CB	0.152		
4	9	0.151	0.159	0.134	0.038	CB	0.120	B	0.120
Locality	mean	0.166	0.178	0.184	0.074				
	SNK	A	A	A	B				
Region	mean	0.172		0.132					
	SNK	A		A		Grand mean	0.152		

Table 16. Uranium transfer ratios. Student-Newman-Keuls tests for main effects following two-way analysis of variance. Means with the same letter are not significantly different. Group and species codes are listed in Table 5.

		Wollaston Lake		Churchill River		Species		Groups	
		Hidden	Collins	Birch	Otter	SNK		SNK	
Group	Species	Bay	Creek	Hills	Rapids	Test	Mean	Test	Mean
1	2	0.644		0.003		C	0.323	B	0.152
1	6	0.138	0.121	0.002	0.001	C	0.066		
2	1	0.574	0.334	0.009	0.003	C	0.230		
2	3	0.213	0.085	0.003	0.001	C	0.076		
2	4		0.069	0.004	0.001	C	0.025	B	0.115
2	5	0.254	0.159	0.007	0.001	C	0.105		
3	0	3.274	1.321	0.008	0.004	B	1.152		
3	7			0.013	0.004	C	0.009	A	1.169
3	8	2.880	1.848			A	2.364		
4	9	2.848	1.974	0.027	0.006	B	1.214	A	1.214
Locality	mean	1.353	0.739	0.008	0.003				
	SNK	A	B	C	C				
Region	mean	1.046		0.006					
	SNK	A		B		Grand mean	0.510		

3. Radionuclide enrichment factors

A difficulty with the interpretation of transfer ratios is that it is not known whether observed accumulations of elements in plants are soilborne or airborne in origin. If element levels are normalized to a known soilborne element content then it becomes possible, in theory, to separate these two sources of origin. This may be done by the calculation of enrichment factors (Puckett and Finegan 1980).

The enrichment factor (EF) for any element (X) in a plant relative to the soil = $\frac{(X/\text{reference element}) \text{ in plant}}{(X/\text{reference element}) \text{ in soil}}$

Elements that have been used as crustal indicators are the relatively insoluble elements scandium, aluminum and titanium. Scandium was not analyzed in this study and EF values have been calculated using titanium. EF values for radionuclides are summarized in Tables 17-20 and in Appendix IV for other elements. Values greater than unity theoretically suggest enrichment above soil values but in practice values up to 5 are still taken to indicate a crustal source. Alternative sources include elements accumulated by cation exchange from the soil and from airborne sources other than soil particulates, including anthropogenic sources.

Pb^{210} enrichment factors are significantly higher overall in the Wollaston Lake region than the Churchill River region, due to high levels at the Collins Creek locality (Table 17) where five of seven comparable species have their largest values. The average EF values for the southern localities suggests that plant Pb^{210} content is close to equilibrium with the soil Pb^{210} although the two Vaccinum spp. (1 and 5), Cladina stellaris (0) and moss (9) at 'Birch Hill' have

Table 17. Pb^{210} enrichment factors. Means with the same letter are not significantly different (SNK test). Group and species codes are listed in Table 5.

		Wollaston Lake		Churchill River		Species		Group	
		Hidden	Collins	Birch	Otter	SNK		SNK	
Group	Species	Bay	Creek	Hills	Rapids	Test	Mean	Test	Mean
1	2	1.57		1.41		A	1.49	A	13.38
1	6	37.02	37.86	1.95	0.45	A	19.32		
2	1	8.88	162.63	8.81	1.81	A	45.53		
2	3	2.46	30.52	0.72	0.48	A	8.55		
2	4		73.26	2.72	0.30	A	25.43	A	31.16
2	5	147.55	17.92	7.42	1.94	A	43.71		
3	0	4.56	26.83	12.56	1.77	A	11.43		
3	7			3.26	0.62	A	1.94	A	9.89
3	8	4.20	25.29			A	14.74		
4	9	5.15	75.84	6.70	1.62	A	22.33	A	22.33
Locality	mean	26.42	56.27	5.06	1.13				
	SNK	B	A	B	B				
Region	mean	41.346		3.209					
	SNK	A		B		Grand mean		21.7	

relatively high values.

The lichens have the lowest average EF values, which although not significantly different from the other groups, is consistent with the theory that they procure their nutrients by entrapment of soil particulates. Nevertheless the values for the non-vascular plants at Collins Creek and for Cladina stellaris (0) at "Birch Hills" are larger than can be accounted for by soil particulate entrapment alone. Higher values for other groups, and possibly including the moss Pleurozium schreberi (9), suggest uptake by cation exchange from the soil.

The remaining radionuclides (Tables 18-20) vary in a similar manner to Pb^{210} but uranium shows the largest difference in EF values between the two regions. Lichens have the lowest EF values and shrubs the highest, except for uranium where moss is the highest. Ra^{226} is the only radionuclide to show a significantly larger average EF for the shrubs than the other species groups. The single EF value within the non-vascular plants that might be the result of soil particulate uptake is Ra^{226} for the lichens.

The univariate analyses show significant differences in radionuclide levels between regions and localities within regions for numerous species. These relationships are summarized in Table 21 which indicates that the shrubs are the most discriminating species between regions and the trees and moss between localities within regions. The overall levels of accummulation were higher in the Wollaston Lake region than the Churchill River region despite the inverse relationship for soil radionuclides. Lichen and moss species have the highest levels of accumulation of all radionuclides with the

Table 18. Po^{210} enrichment factors. Means with the same letter are not significantly different (SNK Test). Group and species codes are listed in Table 5.

		Wollaston Lake		Churchill River		Species		Group	
		Hidden	Collins	Birch	Otter	SNK		SNK	
Group	Species	Bay	Creek	Hills	Rapids	Test	Mean	Test	Mean
1	2	2.24		0.83		A	1.53	A	11.33
1	6	38.27	24.97	1.35	0.34	A	16.23		
2	1	6.64	77.42	6.07	0.74	A	22.72		
2	3	1.35	17.00	0.43	0.25	A	4.76		
2	4		32.21	1.51	0.13	A	11.28	A	19.50
2	5	129.73	13.04	4.79	1.24	A	37.20		
3	0	4.75	18.35	8.96	1.01	A	8.27		
3	7			2.49	0.29	A	1.39	A	7.16
3	8	3.61	17.85			A	10.73		
4	9	5.55	57.04	3.39	0.95	A	16.73	A	16.73
Locality mean		24.02		32.23	3.31	0.62			
	SNK	A		A	B	B			
Region	mean		28.13			2.05			
	SNK		A			B	Grand mean		14.7

Table 19. Ra^{226} enrichment factors. Means with the same letter are not significantly different (SNK test). Group and species codes are listed in Table 5.

		Wollaston Lake		Churchill River		Species		Group	
		Hidden	Collins	Birch	Otter	SNK		SNK	
Group	Species	Bay	Creek	Hills	Rapids	Test	Mean	Test	Mean
1	2	4.67		5.08		C	4.88	B	31.52
1	6	112.85	26.86	19.04	20.59	C	44.84		
2	1	32.02	381.16	227.78	7.80	AB	162.19		
2	3	29.04	250.12	37.80	25.70	BC	85.67		
2	4		132.73	73.53	5.60	BC	70.62	A	136.39
2	5	389.05	144.43	210.66	98.36	A	210.62		
3	0	2.32	6.66	4.50	0.56	C	3.51		
3	7			2.85	0.39	C	1.62	B	4.92
3	8	3.78	18.28			C	11.03		
4	9	3.98	56.35	7.91	1.85	C	17.52	B	17.52
Locality mean		72.21	127.07	65.46	20.11				
	SNK	AB	A	AB	B				
Region	mean	99.64		44.12					
	SNK	A		B				Grand mean	71.0

Table 20. Uranium enrichment factors. Means with the same letter are not significantly different (SNK test). Group and species codes are listed in Table 5.

		Wollaston Lake		Churchill River		Species		Groups	
		Hidden	Collins	Birch	Otter	SNK		SNK	
Group	Species	Bay	Creek	Hills	Rapids	Test	Mean	Test	Mean
1	2	59.00		0.69		A	29.85		
1	6	336.86	120.23	0.76	0.34	A	114.55	A	86.31
2	1	75.36	381.72	6.23	0.70	A	116.00		
2	3	18.28	68.03	0.31	0.16	A	21.70		
2	4		86.26	2.17	0.19	A	29.54		
2	5	1003.55	117.66	3.96	0.55	A	281.43	A	117.68
3	0	73.66	123.14	1.34	0.28	A	49.60		
3	7			0.72	0.12	A	0.42		
3	8	80.31	216.99			A	148.65	A	62.07
4	9	77.94	604.18	2.01	0.34	A	171.12	A	171.12
Locality	mean	215.62	214.76	2.02	0.34				
	SNK	A	A	B	B				
Region	mean	215.20		1.23					
	SNK	A		B		Grand mean		105.0	

Table 21. Number of significant differences in radionuclide accumulation (ANOVA) for species within groups between regions and between localities within regions.

Species Group	No. Species	Pb^{210}	Po^{210}	Ra^{226}	U^{TOT}	Percentage Max. No.
Between Regions						
Trees	2	1	-	-	2	37.5
Shrubs	4	3	2	1	4	62.5
Lichens	1	-	-	1	1	50.0
Moss	1	-	-	-	1	25.0
Total	8	4	2	2	8	50.0
Between Localities Within Regions						
Trees	1	1	-	-	1	50.0
Shrubs	4	1	-	3	-	25.0
Lichens	3	1	-	-	-	8.3
Moss	1	-	-	1	1	50.0
Total	9	3	-	4	2	25.0

exception of Ra^{226} for which the shrubs are the highest (Table 22). Uranium is the only radionuclide for which trees have a higher accumulation than shrubs. Calculated transfer ratios from soil to plants were not informative. Enrichment factors are lowest for the lichens but only the values for Ra^{226} are low enough to suggest that soil particulates are the major source of accumulation. The highest EF values are for Ra^{226} in shrubs and for uranium in moss.

Multivariate analysis

The total data set comprises 111 (99 vegetation and 12 soil) samples with measurements for 24 radionuclides and elements. This matrix was subject to PCA the results of which are shown in Table 23 and Figure 2. The success of the analysis is initially indicated by the fact that 75% of the variance in the data is extracted in the first three components and 90% in the first seven components.

Crust-derived elements with high positive loadings (0.25) on the first component include aluminum, chromium, iron and titanium. These elements are distributed in airborne dust (Puckett and Finegan, 1980). Beryllium, cadmium, Pb^{210}, Po^{210} and lead are also highly correlated with this component. Pb^{210} and Po^{210} are disintegration products of radon gas and are therefore distributed in the atmosphere. Lead also behaves in the same manner when derived from gasoline combustion and its accumulation levels and EF values are highest for "Birch Hill" (Appendices II and IV) the study locality closest to a road. At this locality the road adjacent to the collecting sites is much more heavily used than in the north with much evidence of dust on the vegetation close to the road but not at the sites themselves. The

Table 22. Rank order of accumulation of radionuclides by species group (1, low - 4, high).

	No. Species	Pb^{210}	Po^{210}	Ra^{226}	U^{TOT}
Trees	2	1	1	1	2
Shrubs	4	2	2	4	1
Lichens	3	3	3	2	3
Moss	1	4	4	3	4

Table 23. Principal components analysis of the total data set (including the soils). Components 1-7 are the vectors of transformation coefficients giving the correlation of the nuclides with the respective principal components extracted by the analysis.

	COMPONENTS						
	1	2	3	4	5	6	7
Pb^{210}	0.259	0.101	0.165	0.212	-.090	-.220	-.189
Po^{210}	0.263	0.064	0.191	0.208	-.091	-.208	-.172
Ra^{226}	-.035	0.138	0.086	0.557	0.080	0.716	0.113
Uranium	0.153	0.038	0.400	0.227	-.341	-.253	0.623
Boron	-.219	0.272	0.043	-.016	0.050	-.014	0.129
Phosphorus	0.022	0.346	-.127	-.138	-.247	0.023	0.051
Silver	-.207	0.114	0.310	-.007	0.393	0.002	0.160
Aluminum	0.276	0.022	-.010	0.012	0.207	-.103	0.236
Beryllium	0.281	0.009	-.194	-.065	-.065	0.037	-.024
Calcium	-.241	0.217	0.117	0.026	-.008	0.046	-.125
Cadmium	0.256	0.153	0.137	-.152	0.196	0.051	-.081
Cobalt	0.184	0.140	-.479	0.024	-.093	-.026	0.119
Chromium	0.250	-.066	0.059	-.167	0.201	0.179	0.133
Copper	-.113	0.273	-.253	0.217	0.280	-.225	-.160
Iron	0.288	-.011	-.048	0.117	0.126	0.012	-.096
Potassium	-.034	0.259	0.136	-.150	-.586	0.260	-.228
Magnesium	-.171	0.294	-.204	0.153	-.039	-.124	-.005
Manganese	-.084	0.365	0.215	-.003	0.149	-.103	-.098
Sodium	0.213	0.275	0.055	0.089	0.103	-.056	-.164
Nickel	0.054	0.311	-.352	-.038	-.007	0.030	0.443
Lead	0.270	0.100	0.078	-.035	-.058	0.114	-.196
Titanium	0.250	-.090	-.092	0.044	0.062	0.296	0.010
Vanadium	0.224	0.237	0.083	0.034	0.115	-.040	-.066
Zinc	0.074	0.235	0.173	-.594	0.127	0.174	0.125
Eigenvalue	10.7	5.6	1.6	1.3	1.0	0.8	0.6
% Trace	44.7	23.1	6.7	5.5	4.2	3.3	2.4
% Cumulative Trace	44.7	67.9	74.6	80.2	84.4	87.7	90.1

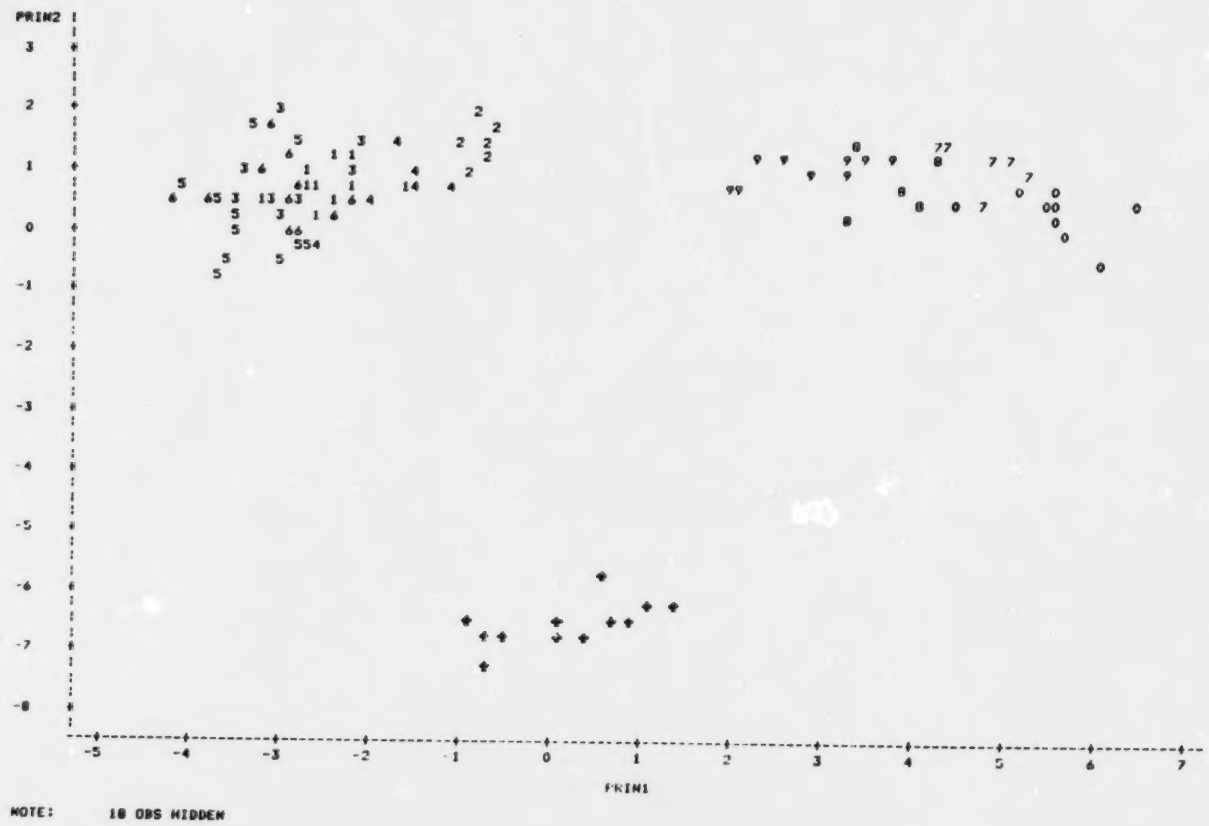

Figure 2. Principal component analysis of total data set. Ordination of species scores (including soil) on the first two components. Species codes are as follows: -

Vascular plants - 1 Vaccinium myrtilloides
2 Pinus banksiana
3 Ledum groenlandicum
4 Alnus crispa
5 Vaccinium vitis-idaea
6 Picea mariana

Non-vascular plants - 0 Cladina stellaris
7 C. rangiferina
8 C. mitis
9 Pleurozium schreberi

Soil +

relatively high negative loadings (> -0.20) on the first component for boron, silver and calcium are due to the fact that they are least accumulated in lichens and mosses (Appendices II and IV).

It may be concluded that the first component represents elements accumulated by particulate entrapment. This conclusion is supported by the distribution of species on the first component shown in Figure 2. Lichens and mosses, which efficiently trap airborne particulates, form a discrete group (7-0) at the positive end while the vascular plants (1-6) occupy the negative end of the component. The soils (+) are intermediate in position on the first component, that is they have no correlation with the component, as would be expected.

While the non-vascular and vascular plants are distinctly separated on the first component some of their constituent species are also separable. Amongst the non-vascular species Cladina stellaris (0) has the highest positive loadings and is therefore the most efficient accumulator of airborne materials. The moss Pleurozium schreberi (9) has the lowest loadings amongst the non-vascular plants and therefore behaves more similarly to the vascular plants than any of the lichens. Its position may reflect an additional accumulation of elements in throughfall from Picea mariana (6), under which it grows most abundantly. In contrast Cladina stellaris (0) grows in the most xeric environment, in open glades between the trees. Cladina rangiferina (7) and C. mitis (8) occupy intermediate positions both on the component and on the ground but they cannot be compared more directly since they were not collected in both regions.

The second component is highly loaded (> 0.20) for essential elements required by plants, that is boron, phosphorus, calcium,

copper, potassium, magnesium, manganese and zinc, but excluding iron (Table 23). Although iron is required by plants, in the acid soils of northern Saskatchewan it is freely available and need not be accumulated in amounts substantially different from soil levels. Its maximum accumulation in plants is a factor of x3 in lichens, the only essential element recording a factor of > x10 (Appendix II). Other, non-essential elements with high loadings on this component are sodium, nickel and vanadium, and are all accumulated in similar quantities to the essential elements. No element has a high negative correlation with this component. It is not surprising, therefore, that the second component separates the soil samples (+) by a wide margin from the vegetation samples (Figure 2).

Since the soil samples were the only highly loaded samples on the second of the first seven components they were removed for subsequent analyses in the hope that the accompanying reduction in the size of the data matrix would lead to an easier interpretation of the remaining components. The PCA results for the vegetation data alone are given in Table 24. The new analysis results in a higher eigenvalue for the first component and the addition of four elements with scores >0.25; boron, calcium, sodium and vanadium. The first two elements have negative loadings and reflect uptake by vascular plants (Figure 3). Sodium and vanadium add to the list of crustal-elements (Puckett and Finegan 1980) distributed as particulates and taken up by the non-vascular species. Thus the interpretation of the first component of the last analysis is further clarified. Components three to six of the original analysis (Table 23) are very similar to components two to five of the vegetation analysis (Table 24).

Table 24. Principal components analysis of the vegetation data set. Components 1-7 are the vectors of transformation coefficients giving the correlations of the nuclides with the respective principal components extracted by the analysis.

	COMPONENTS						
	1	2	3	4	5	6	7
Pb^{210}	0.239	0.126	0.159	-.175	-.091	0.055	0.116
Po^{210}	0.240	0.147	0.152	-.175	-.100	0.036	0.109
Ra^{226}	-.034	0.026	0.328	-.229	0.787	0.065	-.189
Uranium	0.137	0.239	0.054	-.379	-.151	-.222	-.570
Boron	-.255	0.009	-.037	0.080	0.107	-.068	-.110
Phosphorus	0.044	-.263	-.400	-.144	0.140	0.689	-.195
Silver	-.196	0.280	0.071	0.244	0.134	0.008	-.166
Alumium	0.249	0.019	0.081	0.163	-.025	-.014	-.177
Beryllium	0.256	-.143	-.044	0.013	-.029	-.015	0.053
Calcium	-.256	0.097	-.008	-.037	0.095	-.080	0.117
Cadmium	0.247	0.146	0.053	0.198	0.081	-.043	0.100
Cobalt	0.178	-.403	0.016	0.019	-.001	0.001	0.018
Chromium	0.241	0.061	-.064	0.234	0.173	-.156	-.022
Copper	-.128	-.249	0.372	0.254	0.007	-.014	0.336
Iron	0.259	-.001	0.146	0.049	0.073	0.066	0.071
Potassium	-.032	0.036	-.409	-.442	0.288	-.344	0.465
Magnesium	-.205	-.270	0.131	-.039	0.052	0.149	0.013
Manganese	-.178	0.375	0.073	0.232	0.138	0.145	0.072
Sodium	0.253	0.060	0.134	0.051	0.088	0.147	0.155
Nickel	0.078	-.460	-.030	0.195	0.162	-.471	-.292
Lead	0.251	0.070	-.037	-.052	0.072	-.015	0.159
Titanium	0.232	-.044	0.038	0.035	0.255	-.011	0.029
Vanadium	0.251	0.117	0.063	0.092	0.072	0.138	-.001
Zinc	0.083	0.164	-.533	0.403	0.157	-.035	-.059
Eigenvalue	13.2	2.4	1.8	1.4	1.0	0.8	0.7
% Trace	55.2	10.2	7.4	5.9	4.2	3.3	3.0
% Cumulative Trace	55.2	63.4	72.8	78.7	83.0	86.3	89.3

Component seven of the total data set analysis is resolved into components six and seven of the vegetation analysis.

The highest loadings (0.35) for the second component of the vegetation PCA (Table 24) are negative for cobalt and nickel, and positive for manganese. Reference to Figure 3 shows that the Alnus crispa (4) samples are separated towards the negative pole of the component. Checking the levels for these elements in Appendix II it is found that A. crispa has the highest levels of all vascular species for cobalt (0.831 ug/g) and nickel (3.247 ug/g) and the lowest level of manganese (70.9 ug/g). The second component is therefore unique to A. crispa which has a characteristic uptake pattern for the three elements. It maybe significant that cobalt is a required element for organisms which fix molecular nitrogen (Devlin and Witham, 1983) as A. crispa does. It may or may not be significant that A. crispa is the only truly deciduous species studied.

The third component has very high negative loadings (0.40) for phosphorus, potassium and zinc and relatively high positive loadings (0.30) for Ra^{226} and copper. Figure 4 shows that the two tree species, Pinus banksiana (2) and Picea mariana (6), have the highest negative positions on the axis representing this component, while Vaccinium myrtilloides (1) has the highest positive loadings (with some overlap). Appendix II indicates that amongst the vascular plants the tree species have the highest accumulation of zinc (46.1 ug/g), the second highest for potassium (after moss, 3370 ug/g) and a high level for phosphorus (972 ug/g). They have the lowest levels of Ra^{226} (0.003 Bq/g, Table 10b) and copper (after lichens, 2.32 ug/g). The same elements show a parallel but inverse ordering for V.

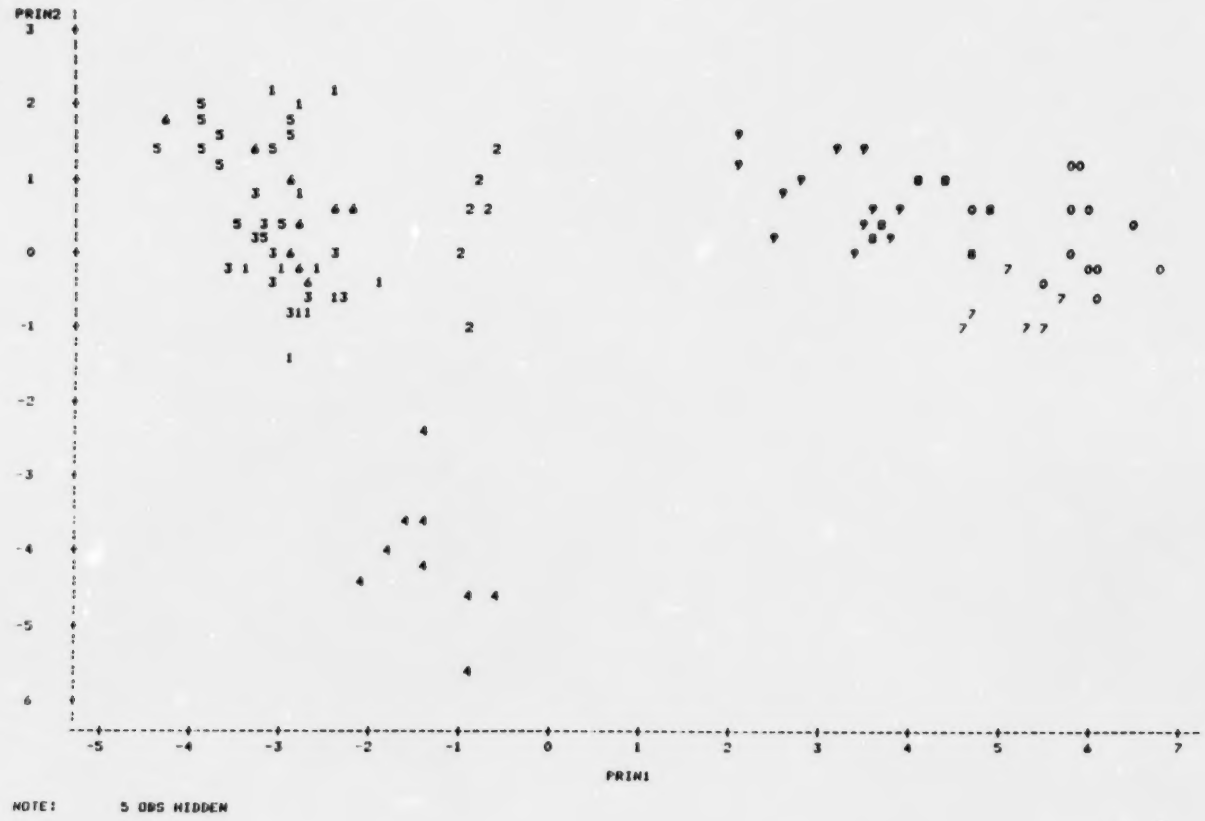

Figure 3. Principal components analysis of vegetation data set. Ordination of species scores on the first two components. Species codes are given in Figure 2.

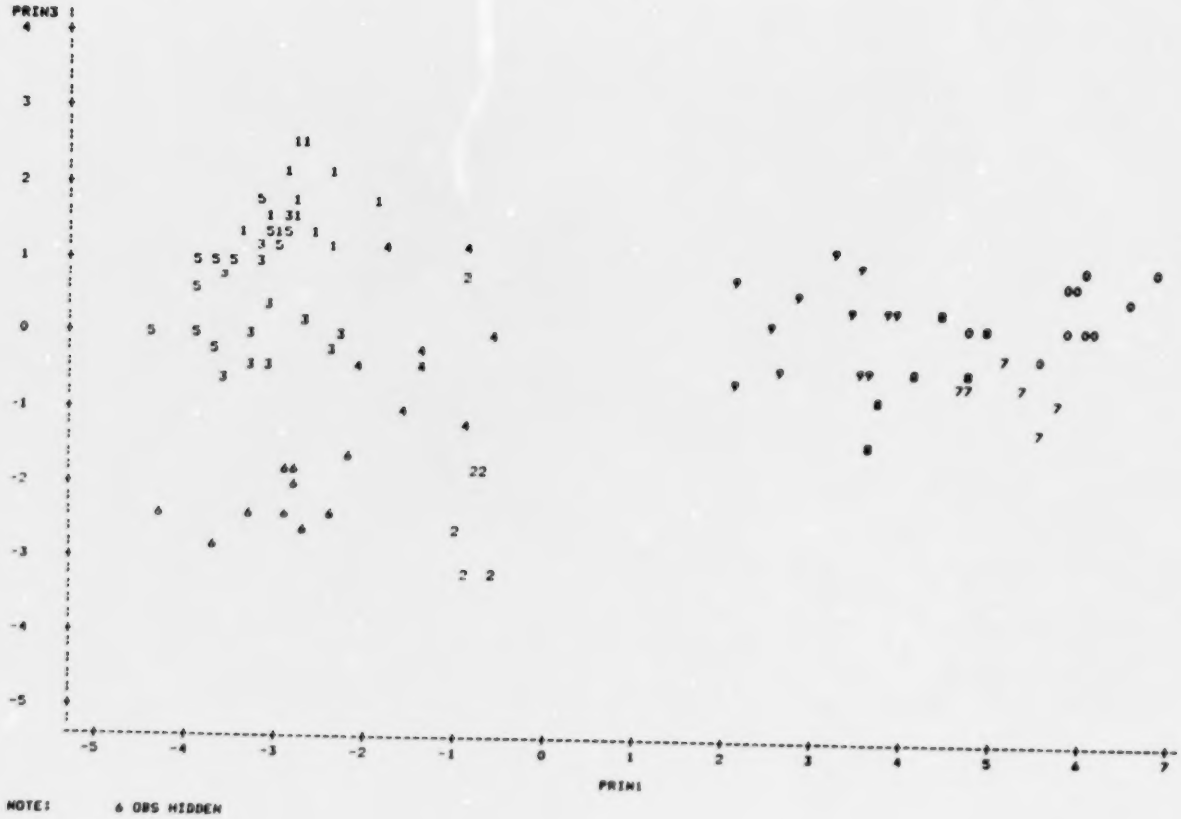

Figure 4. Principal components ordination of species scores on the first and third components for the vegetation data set. Species codes are given in Figure 2.

myrtilloides. It has previously been noted that the shrubs, excluding Alnus crispa, are all relatively high accumulators of Ra^{226} Table 10b.

Potassium has the highest absolute correlation with the fourth component and uranium varies with it; both have a high negative loadings. These elements therefore have an inverse relationship with zinc which has the highest positive loading on the component. Reference to Figure 5 suggests that there is a separation of northern and southern localities amongst the non-vascular plants which would seem to be due to their excessive accumulation of uranium in the Wollaston Lake region (Table 12b). Figure 6, however, shows that the fourth component is dominated by Pinus banksiana (2) which has the highest accumulation of zinc (57.8 ug/g, Appendix II) amongest the vascular plants. The inverse correlation of zinc and uranium is caused by a coincidentally higher accumulation of zinc in the non-vascular plants from southern rather than northern localities. The high negative loading for potassium is due to relatively high accumulation in Picea mariana (6), Vaccinium myrtilloides (1), Ledum groenlandium (3) and Alnus crispa (4) at Collins Creek (Appendix II and Figures 5, 6).

The fifth component is dominated by radium^{226}, the highest loading for any nuclide in the study. This is reflected by the high values of samples of Ledum groenlandicum (3, 0.058 Bq/g) and Vaccinium vitis-idaea (5, 0.062 Bq/g) from Otter Rapids, compare Figures 7 and 8 and Table 10b. This locality had by far the highest values of both Ra^{226} and uranium in the soil (Tables 10b and 12b). Less strongly correlated with this component are potassium and titanium. The latter explains why Otter Rapids has the lowest average enrichment value for

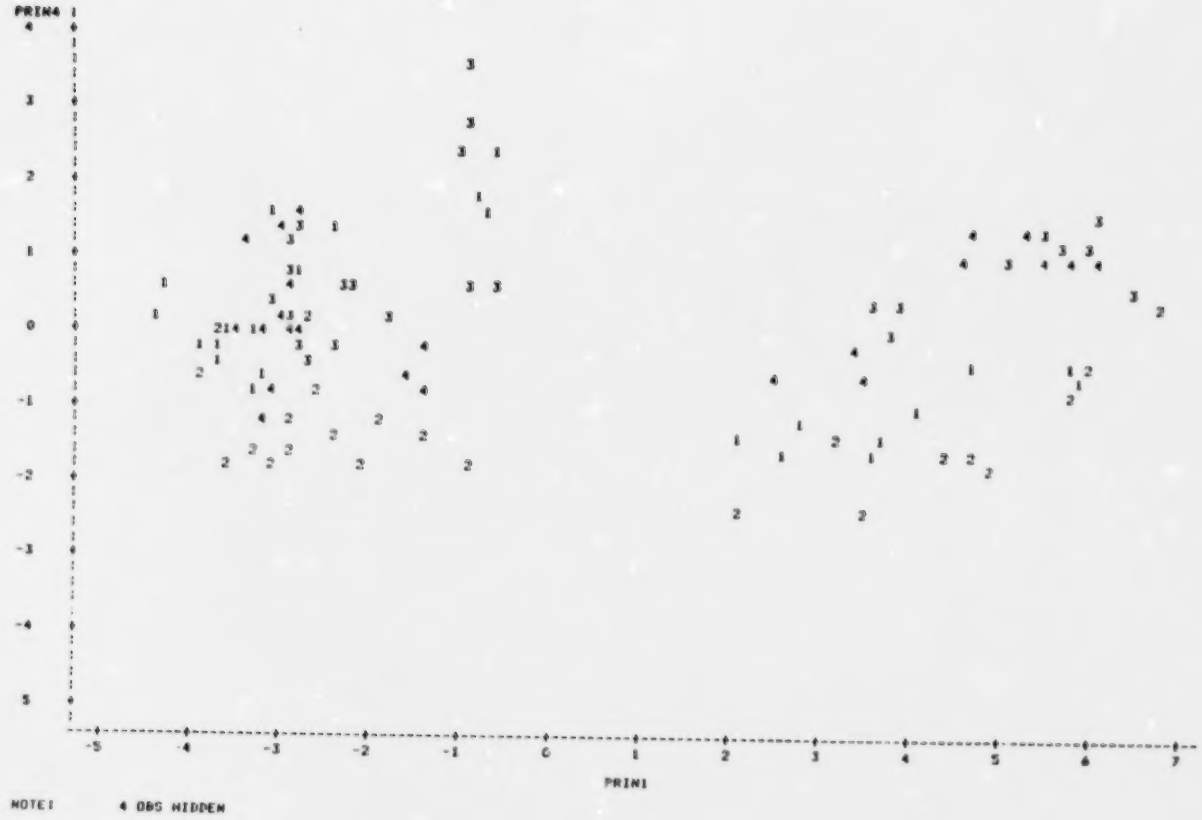

Figure 5. Principal components ordination of locality scores on the first and fourth components for the vegetation data set. Locality codes are: -

Wollaston Lake (region 1, north)		Churchill River (region 2, south)	
1	Hidden Bay	3	'Birch Hill'
2	Collins Creek	4	Otter Rapids

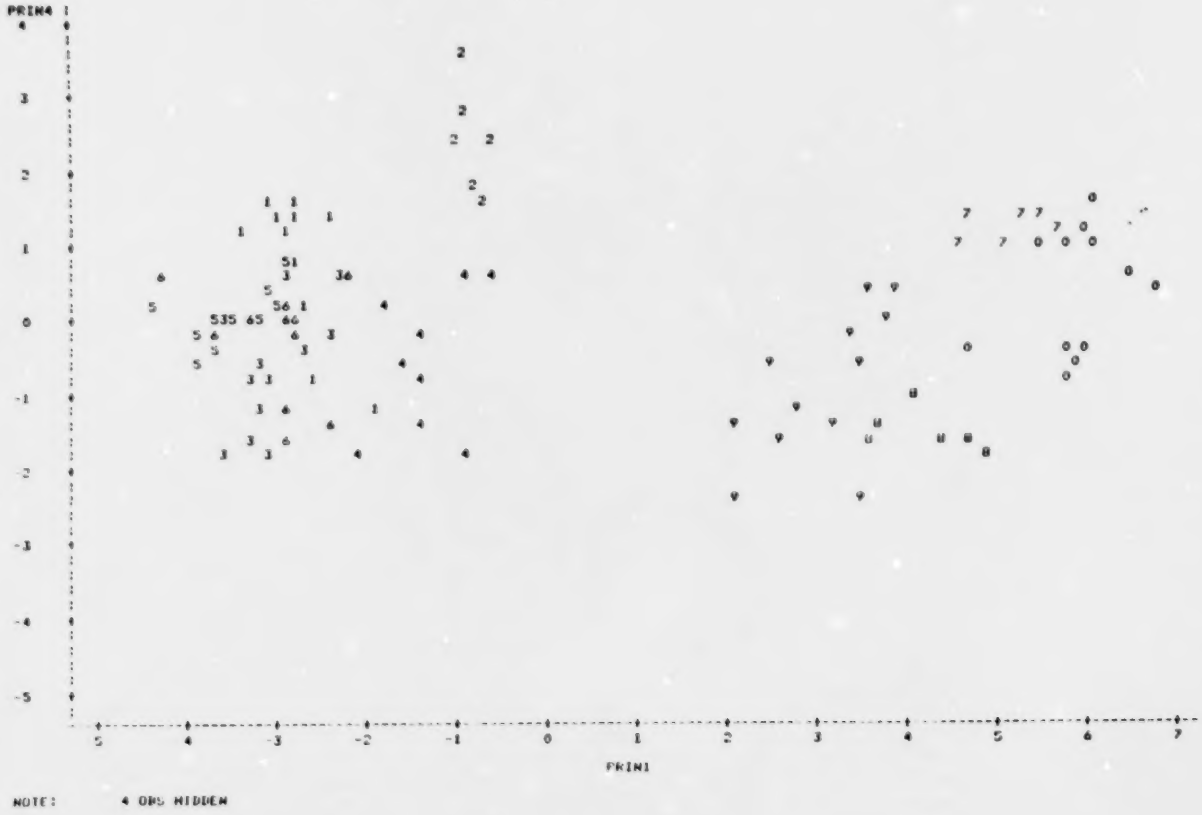

Figure 6. Principal components ordination of species scores on the first and fourth components for the vegetation data set. Species codes are listed in Figure 2.

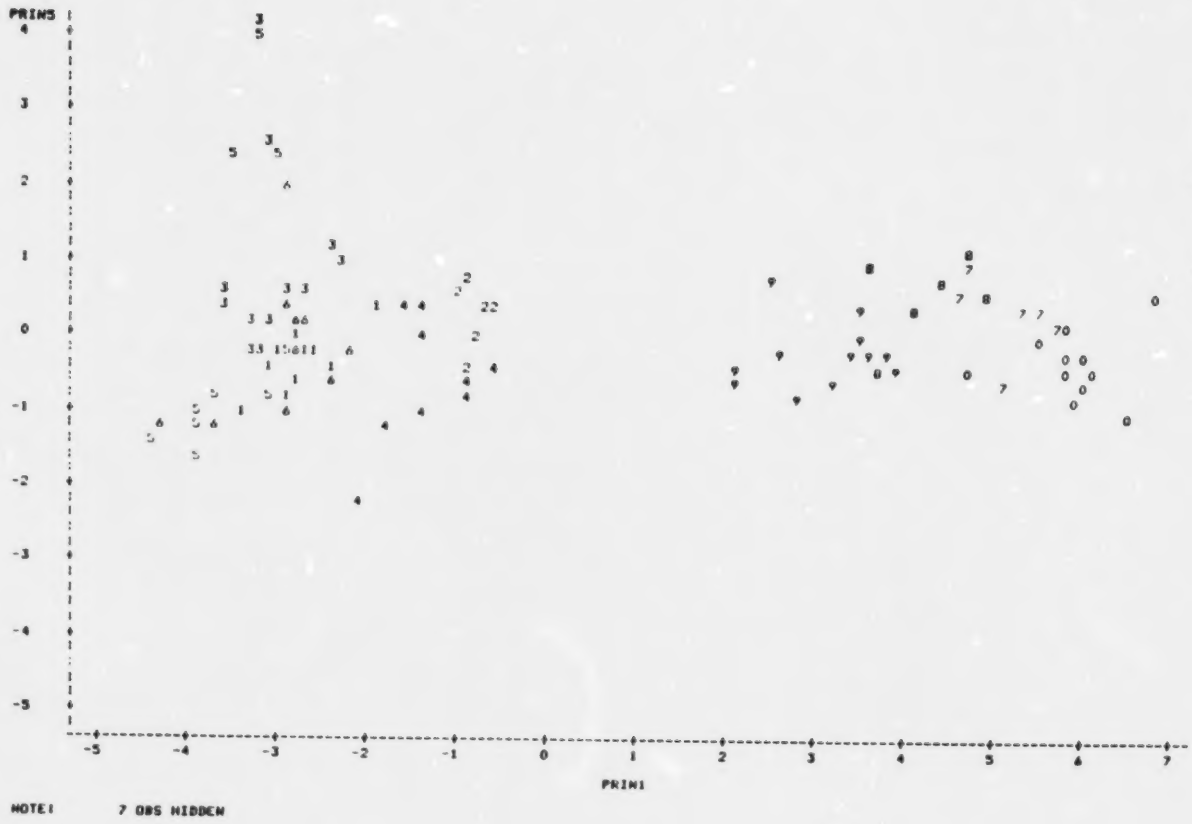

Figure 7. Principal components ordination of species scores on the first and fifth components for the vegetation data set. Species codes are given in Figure 2.

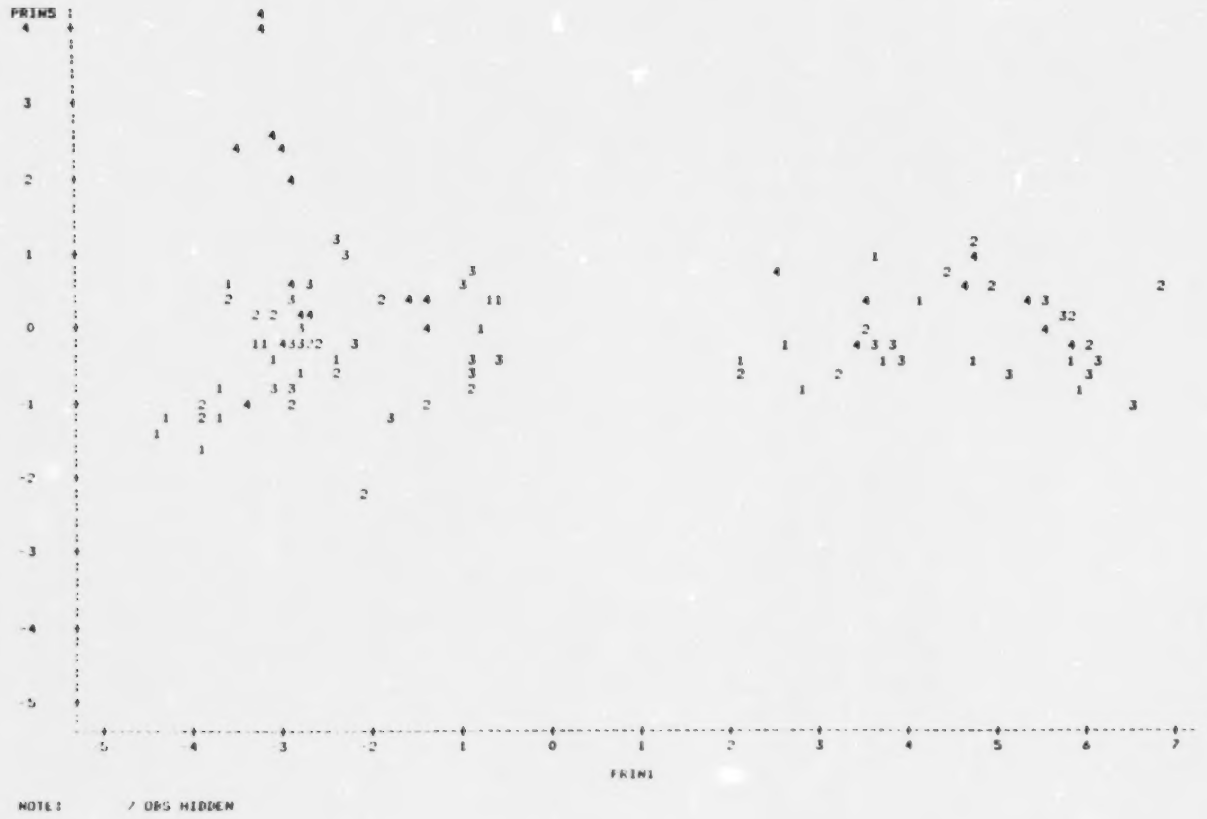

Figure 8. Principal components ordination of locality scores on the first and fifth components for the vegetation data set. Locality codes are given in Figure 5.

most elements (Appendix IV). The fifth component therefore represents high radium^{226} accumulation in two species of shrubs resulting from high soil levels at one locality.

Component six displays an inverse relationship between phosphorus and nickel leading to high positive scores for the non-vascular plants at Otter Rapids relative to 'Birch Hill' on the component (Figures 9 and 10). This interpretation is confirmed by high levels of phosphorus and low nickel at Otter Rapids for the three species concerned (Appendix II).

Uranium has its highest negative loading on component seven where it tends to separate the non-vascular species and the Wollaston Lake and Churchill River regions within most species but especially the non-vascular plants (Figures 11 and 12). The relatively high positive loading for potassium remains unexplained.

The results for the multivariate analyses are summarized in Table 25. It must be emphasized that since the PCA is based on correlations between elements the results represent patterns in accumulation rather than absolute levels of accumulation. The results confirm those of the univariate analyses regarding the high particulate uptake of Pb^{210} and Po^{210} by non-vascular plants and provides additional information on the behaviour of Ra^{226} and uranium. Ra^{226} shows two trends of variation which represent correlations with different shrub species at different localities. Uranium also shows two trends of variation. Firstly, northern and southern localities are separated across all non-vascular species. Secondly, individual non-vascular species tend to be separated on the basis of uranium levels and the regions separated within each species.

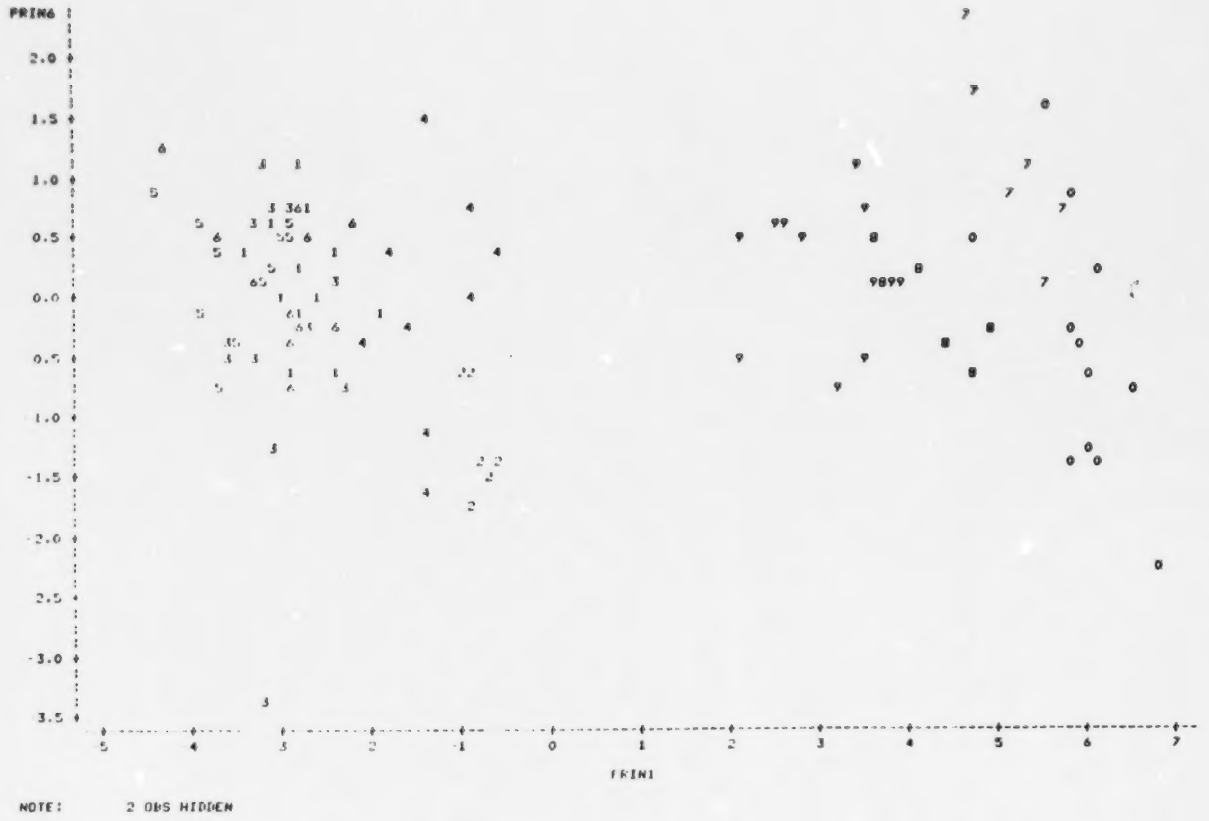

Figure 9. Principal components ordination of species scores on the first and sixth components of the vegetation data sets. Species codes are given in Figure 2.

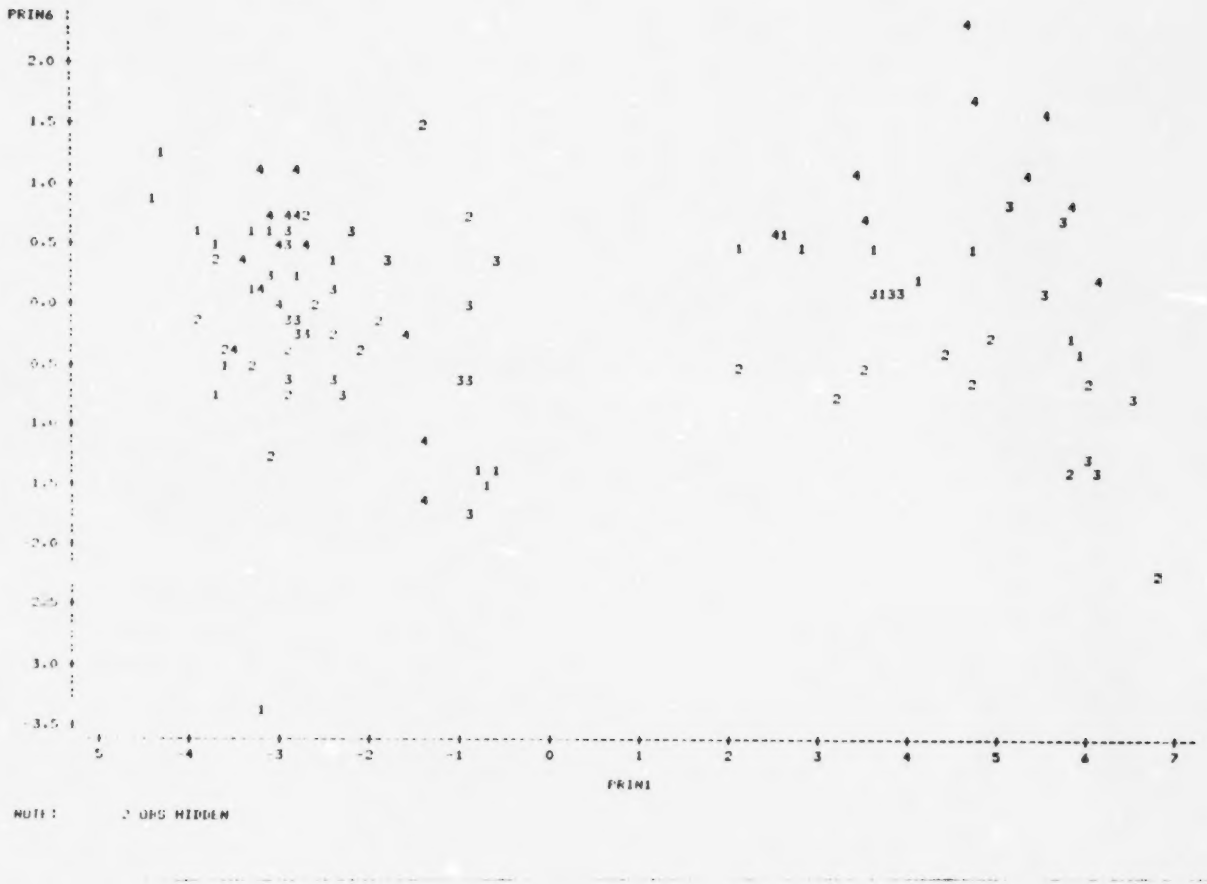

Figure 10. Principal components ordination of locality scores on the first and sixth components for the vegetation data set. Locality codes are given in Figure 5.

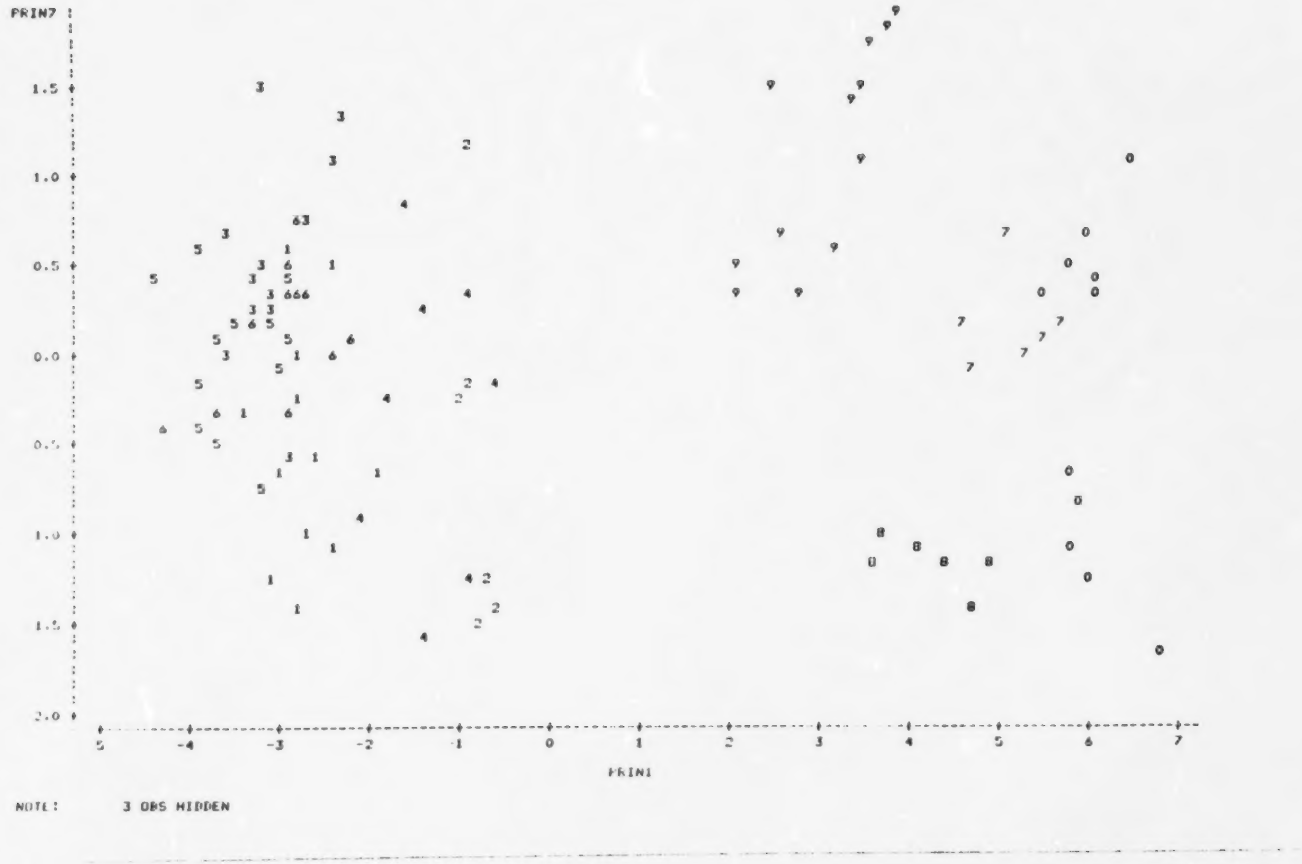

Figure 11. Principal components ordination of species scores on the first and seventh components for the vegetation data set. Species codes are given in Figure 2.

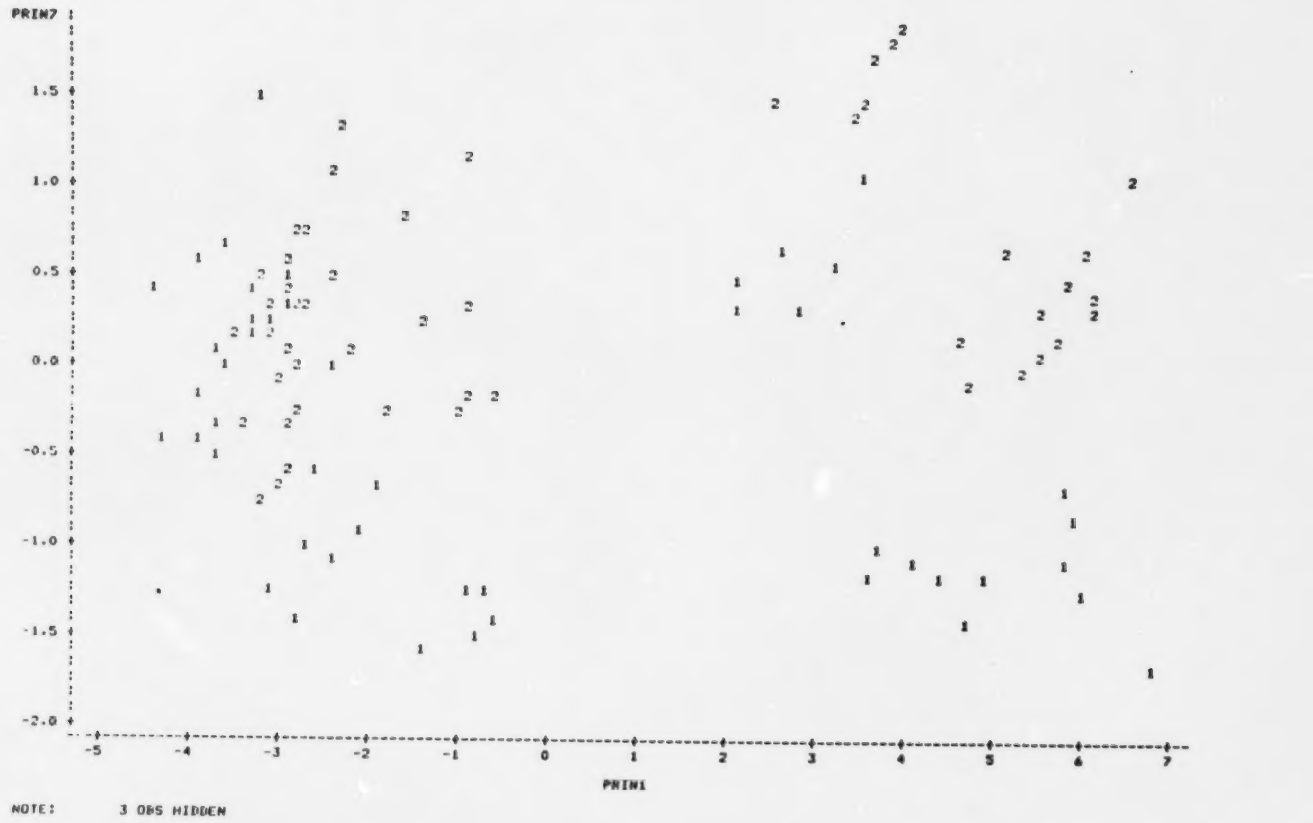

Figure 12. Principal components ordination of region scores on the first and seventh components for the vegetation data set. Region codes are given in Figure 5.

Table 25. Summary of the element, species and locality relationships revealed by PCA. The signs indicate direction of the correlations with the components.

Component	Correlation with component: Element or Radionuclide	Correlation with component: Indicator species and/or collection sites
Total data set		
1	+ Crustal elements distributed in airborne particulates, Pb210, Po210	+ Non-vascular species
2	+ Essential elements, excluding iron	+ All species
Vegetation data set		
1	+ Crustal elements distributed in airborne particulates, Pb210, Po210	+ Non-vascular species
2	+ Manganese, - cobalt and nickel	- Alnus crispa (4)
3	+ Ra226 + Copper - Zinc, potassium and phosphorous	+ Shrubs + Vaccinium myrtilloides (1) - Tree species
4	+ Zinc - Uranium -Potassium	+ Pinus banksiana (2) - Wollaston Lake region within non-vascular species - Vascular plants at Collins Creek
5	+ Ra226	+ Ledum groenlandicum (3) and V. vitis-idaea (5) at Otter Rapids
6	+ Phosphorus, - nickel	+ non-vascular species at Otter Rapids.
7	- Uranium	- Separates the non-vascular species and regions within these species

DISCUSSION

The levels of Pb^{210} and Po^{210} reported in this study for northern Saskatchewan are of the same order as those reported for other northern latitudes from previous studies as shown by Table 26. With the exception of the Cornicularia and Alectoria spp. reported by Holtzman (1966), the Cladina stellaris values are as high as any reported. The highest value of C. stellaris was 0.50 Bq/g dry weight, exceeded only by the moss Pleurozium schreberi with 0.67 Bq/g at the same locality, Collins Creek in the Wollaston Lake region. The average value for shrubs is considerably higher than that reported by Kauranen and Miettinen (1969) in Finland despite the inclusion of twigs in the present study which have lower ash contents (Sheppard and Thibault 1984). Note that the Pb^{210} values for grass in more southern latitudes is generally one order of magnitude less than in lichens. However, in high rainfall areas of the United Kingdom Po^{210}, and probably therefore Pb^{210}, levels may exceed the level in lichens measured in the present study (Hill 1965).

Ra^{226} levels are higher than those previously reported for lichens and mosses by Sheppard et al. (1981, Table 6) but less than those recorded for Cornicularia and Alectoria spp. by Holtzman (1966). Average accumulations for shrubs are two orders larger than recorded for Alnus rugosa along a lakeshore adjacent to a low-grade ore body (Sheppard et al. 1981).

Uranium levels in trees are less than those reported by Dunn (1983a,b) over the Wollaston Lake anomaly but are up to one order of magnitude larger than those reported by Sheppard and Thibault (1984) over a low grade orebody in Ontario. An average value of 3.8 ug/g ash

Table 26. Comparison of radionuclide levels (Pb^{210}, Po^{210}, Ra^{226}) in northern Saskatchewan with those of previous studies. Bq/g dry weight.

Species	Region	N	Pb^{210}	Po^{210}	Ra^{226}
Hill (1965)					
Cladonia alpestris[1]	Lapland	3	-	0.244 - 0.300	-
C. alpestris	Canadian Arctic	1	-	0.129	-
Grass	United Kingdom	24	-	0.015 - 0.593	-
Holtzman (1966)					
C. alpestris	Lapland		0.166	0.485[2]	0.0001
C. sylvatica[3]	Alaska		0.426	0.009	0.0015
Cornicularia + *Alectoria* spp.	Alaska		2.577	-	0.0154
			0.963	-	0.0148
Cladonia sp.	N. Hampshire		0.282	0.271	-
			0.257	0.278	-
Grass, top	Chicago		0.005	0.002	-
centre			0.008	0.002	-
lower			0.026	0.016	-
roots			0.030	0.035	-
Kauranen & Miettinen (1969)					
Cladonia alpestris	Lapland	4	0.207 - 0.378	0.211 - 0.352	-
	S. Finland	9	0.189 - 0.296	0.170 - 0.255	-
Shrubs[4], leaves	South & East Finland	4	0.015 - 0.042	0.004 - 0.012	-

Table 26 (continued)

Present Study					
Cladina stellaris	N. Saskatchewan	12	0.47 ± 0.05[5]	0.34 ± 0.06	0.0032 ± 0.0016
Pleurozium schreberi		12	0.54 ± 0.13	0.37 ± 0.07	0.0076 ± 0.0048
Shrubs, twigs & leaves		45	0.09 ± 0.06	0.05 ± 0.04	0.0189 ± 0.0254
Trees, twigs & leaves		18	0.04 ± 0.02	0.03 ± 0.01	0.0035 ± 0.0051

1 Cladina stellaris

2 figure suspect

3 Cladina arbuscula and/or C. mitis

4 Betula and Salix sp., includes seasonal variation

5 standard deviation

wt. (0.09 ug/g dry wt.) has been recorded in this study but the value is based on twig and needle collections rather than twigs alone which were analyzed by Dunn. Uranium accumulation by twigs is 10x that of needles (Dunn 1983b). Shrubs accumulated similar levels of uranium to the tree species in the present study, again less than reported by Dunn (1983b) but more than by Sheppard and Thibault (1984).

It is important to note that the lichens measured in this study have uranium accumulation levels approximately one order larger than for black spruce. If a linear relationship exists between accumulation in lichens and spruce this indicates a potential for levels up to 10,000 ug/g ash wt. in lichens based on the data of Dunn (1983b). It must be stated, however, that due to the number of recent fires in the Wollaston Lake area, lichen woodlands are very much less extensive than regenerating spruce woodland. Moss may be more common and has been shown to accumulate slightly more uranium than lichens. However, moss is not known to be at the base of any important food chain.

Since Pb^{210} and Po^{210} are disintegration products of radon gas they are more widely distributed in the atmosphere than the other two radionuclides studied and were expected to be preferentially accumulated by lichens and mosses compared to the vascular plants. Their levels have proved to be approximately one order higher in the non-vascular plants than the vascular plants and the soil. There is a small but significantly larger overall accumulation in the Wollaston Lake region despite the higher soil levels in the south. However, the total values for the soil do not reflect the amount available for root uptake so that the calculated transfer ratios for these and other

elements are biologically meaningless. Pb^{210} and Po^{210} EF values are lower for lichens than any other group. However, the lichen values at Collins Creek are much larger than would be expected from the accumulation of soil particulates alone; uptake by radon emanation from the soil or particulate uptake from black spruce (Beauford et. al. 1975, 1977) is implicated. The higher average EF value for moss, which is most abundant below black spruce, may favor the latter hypothesis.

In contrast to Pb^{210} and Po^{210} the highest average level of Ra^{226} is found in the shrubs rather than lichens although the difference is not significant. While the level in lichens exceeds that in the trees the EF for the latter, especially Picea mariana, is much greater (but not significantly so) reflecting selective root uptake by trees. The shrubs have significantly higher EF values than the other groups. The results would seem to indicate that Ra^{226} uptake in lichens is generally by trapping of soil particulates. The moss, however, does show enrichment of Ra^{226} with EF values intermediate between that of the lichens and trees. The moss uptake may be directly from the soil or indirectly from the spruce trees under which they grow.

The enrichment factors for uranium show that it is also taken up efficiently by vascular plants. Its accumulation across the plant groups is less variable than Ra^{226} because uranium EF values are an order higher in the lichen and moss species. Nevertheless the pattern of accumulation of uranium and Ra^{226} parallel each other across species, even when the behaviour of the species relative to each other is very different, as it is for Vaccinium myrtilloides and V. vitis-idaea at Hidden Bay and Collins Creek respectively.

The most interesting aspect of uranium accumulation in the plant species studied is the very high level in the non-vascular species. Since uranium in its oxidized state is highly mobile in solution, high levels in vascular plants, such as those reported by Dunn (1983a, b) for Picea mariana, are explicable. Dunn has shown that maximum levels occur in 3-5 year old twigs (stripped of needles) which suggests that the greatest rate of accumulation occurs in the most rapidly growing apical region. It is in this region that there is least loss of needles and consequently little opportunity for loss of potentially toxic uranium in litter fall or by excretion (see below). It is hypothesized that the element is organicially combined and deposited in apical wood thus removing it from the pool of mobile metabolites in the plant. If this is the case it will not be transported down the twigs so that new wood deposited in older parts of twigs will contain little or no uranium and the average content of uranium in the wood of the older parts of twigs will therefore decline.

How can the high levels of uranium observed in the lichens and moss be explained? These plants are poikilohydric, that is they obtain their required water from rain, dew or from the atmosphere, rather than from the ground. It follows therefore that there is little or no transport of elements in solution from the ground into their thalli. The high values of uranium in lichens cannot be explained by transport from the ground although it may be a possibility in the moss Pleurozium schreberi as some mosses are known to have primitive but well developed internal water transport systems (Richardson 1981). Although P. schreberi does not belong to this endohydric group of mosses such a mechanism may be implicated for the

species since it has the highest uranium EF value for any species group. However, uptake from the soil is likely to be relatively inefficient in comparison to the vascular plants and as for the lichens an additional source of uranium is implicated.

Another possible source of uranium besides the soil is the vascular plant biomass, the tree species being the important potential source because of their large biomass in the ecosystem under study. Canopy leaching, stemflow, litter fall and excretion are possible transfer mechanisms between trees and the lichen and moss species. Canopy leaching, stemflow and litter fall may be important transfers for mosses which are typically most abundant under Picea but will be less important for lichens in open Picea and Pinus communities where lichens are most abundant between the widely spaced trees. The transfer mechanism of most importance here may be the loss of wax particles (Beauford et al. 1975, 1977) from the surface of conifer needles. Such particles have been implicated in the cycling of minerals between plant species in the subalpine environment (Curtin et al. 1974) and are the basis of an aerial exploration method for heavy metals described by Barringer (1977). If metals are excreted in large enough amounts to be detected in air samples it seems likely that they could be accumulated in significant quantities by lichens and mosses on the ground.

Enrichment factor values for the moss exceed those for the lichens. If direct transfer of Ra^{226} and uranium is taking place from the vascular to the non-vascular plants it may be significant that the moss grows beneath the tree canopy whereas the lichens are most abundant and were generally collected in the open habitat between the

trees. The fact that some EF values for the non-vascular plants exceed those of the trees would be explained by the long retention time of the radionuclide in the slower growing lichens and moss.

Lichens and mosses have long been recognized as efficient accumulators of airborne pollutants. It has not been previously recognized that they may play an important role in trapping elements naturally distributed in the atmosphere and for which they may act as both a resevoir and an important component in the cycling of such elements. The level of accumulation of radionuclides, particularly uranium, in lichens and mosses in northern Saskatchewan suggests that these plants may act as a natural reservoir from which they are periodically released by the occurrence of forest fires. Since forest fires are of frequent occurrence in these northern woodlands such periodic release of radionuclides may have an important impact on their atmospheric distribution, on aquatic systems and on plant species such as Vaccinium myrtilloides which recover quickly after fire. Current studies include an investigation of radionuclide levels in adjacent burned and unburned communities.

The results of the univariate statistical analyses show very clearly that there are indeed significant differences in the background radiation of vegetation in northern Saskatchewan, both between localities and between the species sampled. However, they do not address the question of the pattern of such variations in a manner that can be easily summarized or which relates to the pattern of accumulation of other elements. This may be done by referring to the results of the multivariate principal component analyses, which were summarized in Table 25. It is emphasized again that the multivariate

analyses are based on a matrix of correlation coefficients between radionuclide and element levels across all samples. Therefore, they reflect trends of variation in the data rather than the absolute levels of the elements recorded in the samples.

The multivariate analysis firstly substantiates the hypothesized difference in element accumulation patterns of the vascular and non-vascular species, the latter being associated with crustal elements usually considered to be accumulated as particulates (Puckett and Finegan 1980). The analysis also confirmed that Pb^{210} and Po^{210} are accumulated as particulates in the lichen and moss species. Secondly, the shrub species are distinguished from trees by their higher Ra^{226} accumulation. There is also an independent correlation of Ra^{226} with two shrub species, Ledum groenlandicum and Vaccinium vitis-idaea, at Otter Rapids, the locality with highest levels of Ra^{226} in the soil. In neither of these patterns of association was Ra^{226} correlated with calcium, the element to which it is chemically most similar amongst those studied. Thirdly, uranium accumulation was shown to vary most within the non-vascular species. This variation was by region across all species and also by region within individual species.

The multivariate analyses therefore summarize and confirm trends identified in the univariate analysis of the radionuclide data. They also add new information in that they show the Ra^{226} and uranium data each to have two trends of variation. In the same way, the multivariate analyses summarize the major trends of variation in the data for the remaining elements showing a number of relationships that have not previously been reported in the literature. Perhaps the most

important finding was that Ra^{226} and uranium do not covary with and hence do not mimic, any of the other elements analyzed in the study. Their patterns of accumulation in the vegetation cannot therefore be modelled by reference to any other element whose behaviour is better understood or more easily studied.

In terms of the original objectives of this preliminary study it has been shown that there are significant differences in the patterns of radionuclide accumulation in upland vegetation at different localities in northern Saskatchewan. In addition there are significant differences in accumulations between species, and especially between species groups, within localities. Since lichens and mosses dominate the ground floor of most unburned, upland woodlands they form an important resevoir for Po^{210}, Pb^{210} and uranium. There is potential for the transfer of these radionuclides through the lichen-caribou food chain to man, of uranium through spruce needles to spruce grouse and of Ra^{226} through shrubs to moose and bear, and possibly shrub berries to man.

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Literature Cited

Barringer. (1977). AIRTRACE--an airborne geochemical exploration technique. In Woll, P.W. and W.A. Fischer (eds.) U.S. Geol. Survey Prof. Paper 1015, 231-252.

Beauford, W., J. Barber, A.R. Barringer. (1975). Heavy metal release from plants to the atmosphere. Nature 256: 35-37.

Beauford, W., J. Barber and A.R. Barringer. (1977). Release of particles containing metals from vegetation into the atmosphere. Science 195: 571-573.

Beckett, P.J., L.J.R. Boileau, D. Padovan and D.H.S. Richardson. (1982). Lichens and mosses as monitors of industrial activity associated with uranium mining in northern Ontario, Canada. Part 2. Distance dependent uranium and lead accumulation patterns. Environ. Pollut. (B) 4: 91-107.

Black, R.A. and L.C. Bliss. (1970). Reproductive biology of black spruce at treeline. Ecol. Monogr. 5: 331-354.

Boileau, L.J.R., P.J. Beckett, P. Lavoie, D.H.S. Richardson and E. Nieboer. (1982). Lichens and mosses as monitors of industrial activity associated with uranium mining in northern Ontario, Canada. Part 1. Field procedures, chemical analysis and interspecies comparisons. Environ. Pollut. (Series B) 4: 69-84.

Cannon, H.L. (1952). The effect of uranium-vanadium deposits on the vegetation of the Clorado Plateau. Amer. J. Sci. 250: 735-770.

Carroll, S.B. and L.C. Bliss. (1982). Jack pine-lichen woodland on sandy soils in northern Saskatchewan and northeastern Alberta.

Can. J. Bot. 60: 2270-2282.

Curtin, G.C., H.D. King and E.L. Mosier. (1974). Movement of elements into the atmosphere from coniferous trees in subalpine forests in Colorado and Idaho. J. Geochem. Explor. 3: 245-263.

Devlin, R.M. and F.H. Witham. (1983). Plant physiology. 4th edition, Hillard Grant, Boston.

Dunn, C.E. (1983a). Uranium biogeochemical of the NEA/IAEA Athabasca test area. In Uranium exploration in Athabasca Basin, Saskatchewan, Canada, ed. E.M. Cameron. Geol. Survey of Canada Paper 82-11: 127-132.

Dunn, C.E. (1983b). Detailed biogeochemical studies for uranium in the NEA/IAEA Athabasca test area. In Uranium Exploration in Athabasca Basin, Saskatchewan, Canada, ed. E.M. Cameron. Geol. Survey Can. Paper 82-11: 259-272.

Fassel, V.A. and R.N. Knisely. (1974). Inductively coupled plasmas. Anal. Chem. 46: 1157A-1164A.

Folkeson, L. (1979). Interspecies calibration of heavy-metal concentrations in nine mosses and lichens: -applicability to deposition measurements. Water, Air and Soil Pollution 11: 253-260.

Francis, C.W., G. Chesters & W.H. Erhardt. (1968). ^{210}Polonium entry into plants. Environ. Sci. & Technol. 2: 690-695.

Gauch, H.G. (1982). Multivariate analysis in community ecology. Cambridge Univ. Press, New York.

Gittins, R. (1969). The application of ordination techniques. Symp. Brit. Ecol. Soc. 1968, 37-66.

Green, R.H. (1980). Multivariate approaches in ecology: the

assessment of ecologic similarity. Ann. Rev. Ecol. Syst. 11: 1-14.

HASL. (1972). Health and Safety Laboratory, U.S. Atomic Energy Commision. Procedures Manual, New York.

Hill, C.R. (1965). Polonium-210 in man. Nature 208: 423-428.

Hill, C.R. (1966). Polonium-210 content of human tissues in relation to dietary habits. Science 152: 1261-1262.

Holtzman, R.B. (1966). Natural levels of lead-210, polonium-210 and radium-226 in humans and biota of the Artic. Nature 210: 1094-1097.

I.C.R.P. (1979) Limits for intake of radionuclides by workers. Annals of the I.C.R.P., Vol. 2. Permagon Press, New York.

Kauranen, P. and J.K. Miettinen. (1969). ^{210}Po and ^{210}Pb in the artic food chain and the natural radiation exposure of Lapps. Health Physics 16: 289-295.

Knoll, D.C. (1980). The Key Lake Project; impact of uranium development on traditional native harvesting rights. Canadian Native Law Reporter 2: 1-60.

McDowell-Boyer, L.M., A.P. Watson, and C.C. Travis. (1979). Review and recommendations of close conversion factors and environmental transport parameters for ^{210}Pb and ^{226}Ra. Oak Ridge national Laboratory Rep. NUREG-56, pp. 62.

O'Riordan, M.C. (1983). Natural radiation risks. Nature 306:225-226.

Orloci, L. (1978). Multivariate analysis in vegetation research. Junk, The Hague.

Pielou, E.C. (1984). The interpretation of ecological data. Wiley,

Toronto.

Puckett, K.S. & E.S. Finegan. (1980). An analysis of the element content of lichens from the Northwest Territories, Canada. Can. J. Bot. 58: 2073-2089.

Richardson, D.H.S. (1981). The biology of mosses. Wiley, New York.

Rowe, J.S. (1984). Lichen woodland in northern Canada. In Olson, R. (edit.) Northern ecology and resource management, pp. 225-237. Univ. Alberta Press, Edmonton.

SAS (1982). SAS users guide: Statistics. SAS Inst. Inc., Cany N.C.

SENES. (1983). Potential Co-carcinogens in the uranium mine environment. Senes Consultants Ltd., Willowdale, ON.

Shemilt, L.W. (1983). Fourth annual report of the technical advisory committee on the nuclear waste management program. AECL Report TAC-4, 122 pp.

Sheppard, M.I. (1980). The environmental behaviour of uranium and thorium. Atomic Energy of Canada Ltd.: Rep. AECL-6795.

Sheppard, M.I. and D.H. Thibault. (1984). Native plant ^{NAT}U concentration over a low grade onebody. Can. J. Bot. 62: 1069-1075.

Sheppard, M.I., L. Olchony and K.R. Maron. (1981). Uranium, thorium, radium and arsenic concentrations of plants and soils of the Precambrian Shield: a preliminary study. Atomic Energy of Canada Ltd., TR-159.

Smithson, G.L. (1979). Radiochemical procedures for determination of selected members of the uranium and thorium series. CANMET Report 78-22, 65 pp.

Sokal, R.R. and F.J. Rohlf. (1981). Biometry. Freeman, San

Francisco.

S.P.R.R. (1983). Ecological Regions of Saskatchewan. Saskatchewan Parks and Renewable Resources, Technical Bulletin, No. 10.

Williamson, M. (1972). The Analysis of Biological Populations. London.

APPENDIX 1

The original untransformed data matrix of 111 observations for 26 elements. The codes for the four columns GROUP to LOCAL are as follows:

LOCAL = Locality

1. Hidden Bay
2. Collins Creek
3. 'Birch Hill'
4. Otter Rapids

REGION

1. Wollaston Lake (North)
2. Churchill River (South)

SPECIES	GROUP = Species Group
0) Cladina stellaris (Opiz.) Brodo	3) Lichen
1) Vaccinium myrtilloides Michx.	2) Shrub
2) Pinus banksiana Lamb.	1) Tree
3) Ledum groenlandicum Oeder.	2) Shrub
4) Alnus crispa (Ait.) Pursh.	2) Shrub
5) Vaccinium vitis-idaea L.	2) Shrub
6) Picea mariana (Mill.) BSP.	1) Tree
7) Cladina rangiferina (L.) Harm.	3) Lichen
8) C. mitis (Sandst.) Hale & W. Culb.	3) Lichen
9) Pleurozium schreberi (Brid.) Mitt.	4) Moss
11) Soil	5) Soil

Units of Measurement.

Pb^{210}, Po^{210} Bq/g dry wt.

Ra^{226} Bq/g dry wt.

Uranium-Zinc ug/g dry wt.

Transf - % ash wt.

ORIGINAL VEGETATION (DRY WEIGHT) AND SOIL DATA

OBS	INDIV	GROUP	SPECIES	REGION	LOCAL	PB210	PO210	RA226	URANIUM	BORON	PHOSPHOR	SILVER	ALUMINUM
1	13	1	2	1	1	0.05	0.03	0.0012905	0.619440	10.0659	947.23	0.15228	449.094
2	14	1	2	1	1	0.04	0.04	0.0018616	0.511940	7.6791	907.53	0.08843	421.187
3	15	1	2	1	1	0.03	0.03	0.0025272	0.568620	10.1088	796.07	0.10951	280.098
4	16	1	2	2	3	0.06	0.05	0.0008875	0.008875	2.8400	475.70	0.03905	248.500
5	17	1	2	2	3	0.04	0.02	0.0012426	0.006213	8.6982	919.52	0.06627	329.289
6	18	1	2	2	3	0.04	0.02	0.0007992	0.007992	8.7912	827.17	0.07193	357.642
7	52	1	6	1	1	0.03	0.02	0.0014820	0.064220	9.6330	1244.88	0.14820	39.520
8	53	1	6	1	1	0.03	0.02	0.0012795	0.138186	7.6770	1269.26	0.04094	43.503
9	54	1	6	1	1	0.03	0.03	0.0021896	0.177905	11.2217	1332.92	0.15875	43.792

OBS	BERYLL	CALCIUM	CADMIUM	COBALT	CHROMIUM	COPPER	IRON	POTASS
1	0.025810	4542.56	0.203899	0.10840	0.851730	1.98737	64.525	3200.4
2	0.020943	3676.66	0.255970	0.08145	0.651560	1.97795	55.848	3094.9
3	0.021060	2800.98	0.122148	0.11372	0.673920	2.31660	50.544	3074.7
4	0.012425	1437.75	0.145550	0.03550	0.852000	6.03500	39.050	1562.0
5	0.020710	3562.12	0.202958	0.05799	0.600590	2.27810	57.988	2775.1
6	0.019980	3376.62	0.239760	0.05195	0.539460	1.99800	53.946	2877.1
7	0.012350	4890.60	0.024700	0.03211	0.296400	2.47000	17.290	2173.6
8	0.012795	4887.69	0.017913	0.01280	0.307080	2.22633	15.354	3505.8
9	0.027370	4981.34	0.038318	0.02737	0.437920	3.01070	30.107	4981.3

OBS	MAGNES	MANGAN	SODIUM	NICKEL	LEAD	TITANIUM	VANADIUM	ZINC	TRANSF
1	867.22	634.93	17.2927	1.85832	0.05162	2.06480	0.82592	56.7820	0.02581
2	721.37	707.41	12.7985	1.62890	0.04654	0.83772	0.79118	83.7720	0.02327
3	661.28	488.59	16.0056	1.74798	0.04212	1.81116	0.75816	48.4380	0.02106
4	495.23	282.23	26.6250	1.65075	0.03550	1.72175	0.28400	31.9500	0.01775
5	869.82	356.21	15.3254	1.40828	0.08284	2.27810	0.49704	55.9170	0.02071
6	967.03	353.65	15.9840	1.11888	0.07992	2.39760	0.59940	69.9300	0.01998
7	827.45	899.08	7.4100	0.32110	0.07410	0.02470	0.54340	51.8700	0.02470
8	903.33	711.40	9.9801	0.61416	0.05118	0.02559	0.81888	53.7390	0.02559
9	1004.48	1201.54	13.1376	0.62951	0.10948	0.49266	0.60214	49.2660	0.02737

ORIGINAL VEGETATION (DRY WEIGHT) AND SOIL DATA

OBS	INDIV	GROUP	SPECIES	REGION	LOCAL	PB210	PO210	RA226	URANIUM	BORON	PHOSPHOR	SILVER	ALUMINUM
10	55	1	6	1	2	0.10	0.06	0.0019647	0.218300	4.5843	1019.46	0.01092	61.124
11	56	1	6	1	2	0.07	0.04	0.0011915	0.202555	4.2894	853.11	0.04289	47.660
12	57	1	6	1	2	0.06	0.05	0.0017712	0.243540	3.9852	823.61	0.05314	44.280
13	58	1	6	2	3	0.06	0.05	0.0024672	0.008224	3.9064	861.46	0.06579	94.576
14	59	1	6	2	3	0.02	0.01	0.0024544	0.005664	3.5872	866.59	0.10573	52.864
15	60	1	6	2	3	0.03	0.02	0.0019880	0.003976	4.5724	827.01	0.04771	51.688
16	61	1	6	2	4	0.01	0.01	0.0235200	0.004704	3.9984	1185.41	0.06350	49.392
17	62	1	6	2	4	0.02	0.02	0.0044980	0.008996	3.8233	1209.96	0.01349	40.482
18	63	1	6	2	4	0.03	0.02	0.0094200	0.004710	3.7680	1125.69	0.05181	35.325

OBS	BERYLL	CALCIUM	CADMIUM	COBALT	CHROMIUM	COPPER	IRON	POTASS
10	0.010915	4147.70	0.010915	0.01092	0.283790	1.59359	32.745	4104.0
11	0.023830	4980.47	0.023830	0.02383	0.235917	1.73959	28.596	4122.5
12	0.022140	4472.28	0.022140	0.02214	0.177120	1.48338	26.568	4162.3
13	0.014392	3762.48	0.028784	0.04318	0.226160	1.58312	47.288	2343.8
14	0.018880	3360.64	0.018880	0.04154	0.207680	2.07680	24.544	3681.6
15	0.019880	3657.92	0.019880	0.04771	0.218680	1.76932	27.832	3618.1
16	0.011760	4068.96	0.018816	0.03763	0.517440	2.82240	25.872	4374.7
17	0.011245	3733.34	0.011245	0.01799	0.314860	2.24900	29.237	3868.2
18	0.011775	4333.20	0.030615	0.06359	0.329700	2.23725	30.615	3155.7

OBS	MAGNES	MANGAN	SODIUM	NICKEL	LEAD	TITANIUM	VANADIUM	ZINC	TRANSF
10	884.12	261.96	9.3869	0.74222	0.04366	0.67673	0.67673	34.9280	0.02183
11	962.73	278.81	10.9618	0.57192	0.09532	0.57192	0.42894	33.3620	0.02383
12	1029.51	225.83	11.0700	0.42066	0.26568	0.59778	0.44280	26.5680	0.02214
13	999.22	398.86	14.1864	0.51400	0.06168	2.46720	0.53456	39.0640	0.02056
14	930.78	309.63	9.4400	0.75520	0.15104	0.96288	0.45312	37.7600	0.01888
15	995.99	246.51	13.5184	0.67592	0.07952	0.85484	0.43736	31.8080	0.01988
16	1067.81	468.05	10.8192	2.82240	0.04704	0.42336	0.72912	42.3360	0.02352
17	1079.52	407.07	10.7952	0.96707	0.04498	1.05703	0.74217	42.7310	0.02249
18	942.00	426.25	11.0685	0.54165	0.04710	0.94200	0.70650	40.0350	0.02355

ORIGINAL VEGETATION (DRY WEIGHT) AND SOIL DATA

OBS	INDIV	GROUPS	SPECIES	REGION	LOCAL	PB210	PO210	RA226	URANIUM	BORON	PHOSPHOR	SILVER	ALUMINUM
19	1	2	1	1	1	0.20	0.10	0.0134550	0.50830	9.2690	926.90	0.24817	176.410
20	2	2	1	1	1	0.19	0.14	0.0074775	0.44865	8.9730	1016.94	0.56829	137.586
21	3	2	1	1	1	0.15	0.10	0.0119105	0.57851	11.5702	1191.05	0.68060	183.762
22	4	2	1	1	2	0.30	0.12	0.0207830	0.59380	4.4535	1157.91	0.08907	172.202
23	5	2	1	1	2	0.30	0.17	0.0316700	0.66507	6.6507	1108.45	0.00633	190.020
24	6	2	1	1	2	0.20	0.14	0.0199760	0.57431	3.9952	998.80	0.07241	152.317
25	7	2	1	2	3	0.08	0.07	0.0083950	0.03022	6.3802	839.50	0.07388	184.690
26	8	2	1	2	3	0.11	0.05	0.0137480	0.02062	10.9984	824.88	0.13748	202.783
27	9	2	1	2	3	0.08	0.07	0.0219870	0.01885	10.0512	848.07	0.09737	172.755

OBS	BERYLL	CALCIUM	CADMIUM	COBALT	CHROMIUM	COPPER	IRON	
19	0.005980	5083.00	0.029900	0.02093	0.29900	3.58800	77.740	657.8
20	0.005982	4486.50	0.056829	0.04187	0.47856	4.48650	80.757	1076.7
21	0.006806	4764.20	0.081672	0.02382	0.57851	5.78510	71.463	1157.0
22	0.011876	5938.00	0.026721	0.06532	0.27315	5.04730	80.163	2879.9
23	0.015835	5700.60	0.022169	0.02850	0.44338	4.75050	95.010	2660.2
24	0.009988	2996.40	0.017479	0.04994	0.21474	5.99280	74.910	749.1
25	0.023506	7051.80	0.023506	0.15783	0.43654	8.05920	127.604	1914.0
26	0.030933	7217.70	0.061866	0.21653	0.48118	7.21770	137.480	2130.9
27	0.018846	5653.80	0.021987	0.09737	0.31410	6.59610	128.781	659.6

OBS	MAGNES	MANGAN	SODIUM	NICKEL	LEAD	TITANIUM	VANADIUM	ZINC	TRANSF
19	1166.10	2302.30	27.2090	1.01660	0.02990	0.95680	0.80730	23.6210	0.02990
20	1076.76	3290.10	25.7226	0.95712	0.02991	2.18343	1.10667	28.1154	0.02991
21	1565.38	4423.90	22.1195	1.02090	0.03403	0.88478	1.25911	28.5852	0.03403
22	1692.33	623.49	24.9396	1.60326	0.02969	0.29690	0.77194	15.1419	0.02969
23	2026.88	665.07	17.4185	1.74185	0.03167	2.09022	1.20346	16.7851	0.03167
24	1747.90	699.16	18.2281	1.37335	0.02497	0.62425	0.62425	16.4802	0.02497
25	2216.28	638.02	31.5652	2.31702	0.03358	0.50370	1.00740	16.1184	0.03358
26	1718.50	859.25	41.2440	2.02783	0.10311	0.41244	1.44354	14.7791	0.03437
27	1633.32	785.25	30.7818	1.94742	0.03141	1.03653	1.03653	17.5896	0.03141

ORIGINAL VEGETATION (DRY WEIGHT) AND SOIL DATA

OBS	INDIV	GROUP	SPECIES	REGION	LOCAL	PB210	PO210	RA226	URANIUM	BORON	PHOSPHOR	SILVER	ALUMINUM
28	10	2	1	2	4	0.10	0.02	0.0133560	0.02671	9.3492	1001.70	0.180306	176.967
29	11	2	1	2	4	0.13	0.08	0.0072675	0.02326	15.1164	1046.52	0.212211	186.048
30	12	2	1	2	4	0.09	0.05	0.0050813	0.01793	11.0593	986.37	0.113582	149.450
31	19	2	3	1	1	0.06	0.03	0.0118760	0.19002	15.1419	89.07	0.053442	59.380
32	20	2	3	1	1	0.06	0.02	0.0191310	0.15305	12.8451	1030.34	0.117519	60.126
33	21	2	3	1	1	0.08	0.04	0.0095790	0.22990	17.5615	1363.41	0.076632	63.860
34	22	2	3	1	2	0.08	0.04	0.0181285	0.14782	8.6459	1157.43	0.055780	66.936
35	23	2	3	1	2	0.09	0.06	0.0169140	0.19733	10.1484	1088.13	0.014095	78.932
36	24	2	3	1	2	0.06	0.03	0.0193830	0.12461	9.6915	1234.97	0.044304	60.918

OBS	BERYLL	CALCIUM	CADMIUM	COBALT	CHROMIUM	COPPER	IRON	POTASS
28	0.013356	6010.20	0.036729	0.09683	0.36729	5.00850	103.509	1135.2
29	0.011628	4941.90	0.034884	0.07558	0.46512	5.52330	95.931	726.7
30	0.008967	5081.30	0.014945	0.05978	0.29890	5.08130	86.681	717.3
31	0.029690	6264.59	0.089070	0.04750	0.32659	5.64110	47.504	5581.7
32	0.013665	5684.64	0.016398	0.03553	0.38262	5.73930	43.728	3334.2
33	0.015965	6130.56	0.015965	0.01597	0.41509	4.47020	57.474	4023.1
34	0.027890	6777.27	0.027890	0.02789	0.21196	3.90460	36.257	4713.4
35	0.014095	6511.89	0.014095	0.01410	0.24243	3.94660	39.466	5243.3
36	0.027690	5842.59	0.027690	0.02769	0.22152	4.43040	33.228	5399.5

OBS	MAGNES	MANGAN	SODIUM	NICKEL	LEAD	TITANIUM	VANADIUM	ZINC	TRANSF
28	1869.84	1235.43	20.3679	1.93662	0.03339	1.0685	1.20204	23.7069	0.03339
29	1395.36	1424.43	25.8723	0.58140	0.02907	2.3837	0.98838	17.1513	0.02907
30	1673.84	1046.15	19.4285	1.31516	0.02989	0.5380	0.77714	20.3252	0.02989
31	1235.10	353.31	16.6264	1.45481	0.17814	1.3657	0.53442	11.5791	0.02969
32	1248.98	568.46	14.2116	1.36650	0.05466	1.3665	0.76524	18.5844	0.02733
33	1481.55	750.35	23.6282	0.57474	0.06386	1.9158	0.95790	21.7124	0.03193
34	900.85	309.58	16.7340	0.97615	0.11156	0.8925	0.44624	15.6184	0.02789
35	930.27	222.70	13.5312	1.74778	0.05638	0.7048	0.62018	13.2493	0.02819
36	1052.22	293.51	12.1836	0.80301	0.11076	0.6646	0.38766	15.7833	0.02769

ORIGINAL VEGETATION (DRY WEIGHT) AND SOIL DATA

OBS	INDIV	GROUP	SPECIES	REGION	LOCAL	PB210	PO210	RA226	URANIUM	BORON	PHOSPHOR	SILVER	ALUMINUM
37	25	2	3	2	3	0.06	0.03	0.0110560	0.00829	10.7796	1094.54	0.132672	93.976
38	26	2	3	2	3	0.05	0.02	0.0133350	0.01334	7.2009	1032.13	0.031671	90.678
39	27	2	3	2	3	0.04	0.03	0.0192240	0.00641	13.4568	1252.76	0.121752	99.324
40	28	2	3	2	4	0.05	0.02	0.0477600	0.00716	8.8356	1098.48	0.057312	62.088
41	29	2	3	2	4	0.06	0.04	0.0262400	0.01050	6.8224	981.38	0.062976	86.592
42	30	2	3	2	4	0.04	0.02	0.0998400	0.00998	11.9808	1148.16	0.144768	69.888
43	31	2	4	1	2	0.16	0.06	0.0081375	0.12695	13.3455	2213.40	0.013020	270.165
44	32	2	4	1	2	0.11	0.05	0.0061380	0.13504	4.6035	1503.81	0.006138	116.622
45	33	2	4	1	2	0.12	0.06	0.0078025	0.11860	4.9936	2122.28	0.006242	262.164

OBS	BERYLL	CALCIUM	CADMIUM	COBALT	CHROMIUM	COPPER	IRON	POTASS
37	0.027640	5334.52	0.027640	0.12162	0.44224	6.08080	74.628	4837.0
38	0.013335	5974.08	0.024003	0.05067	0.29337	4.26720	74.676	3947.1
39	0.032040	6119.64	0.057672	0.14738	0.57672	4.48560	76.896	5382.7
40	0.023880	4823.76	0.023880	0.02388	0.31044	3.58200	59.700	3701.4
41	0.013120	5300.48	0.015744	0.07610	0.31488	4.19840	65.600	393.6
42	0.012480	5391.36	0.024960	0.09984	0.27456	4.24320	59.904	4218.2
43	0.065100	3580.50	0.006510	0.78120	0.23436	3.90600	81.375	2376.1
44	0.033759	3375.90	0.018414	0.55242	0.15959	4.60350	15.345	2639.3
45	0.071783	3745.20	0.006242	0.90509	0.23720	3.74520	102.993	3745.2

OBS	MAGNES	MANGAN	SODIUM	NICKEL	LEAD	TITANIUM	VANADIUM	ZINC	TRANSF
37	928.70	818.14	30.4040	1.65840	0.49752	4.4224	0.60808	22.9412	0.02764
38	1197.48	424.05	21.8694	1.25349	0.05334	3.7338	0.80010	18.6690	0.02667
39	1547.53	692.06	26.9136	0.80100	0.38448	4.4856	0.96120	23.3892	0.03204
40	1217.88	534.91	16.7160	0.69252	0.09552	2.8656	0.62088	21.7308	0.02388
41	1377.60	485.44	26.2400	1.20704	0.05248	1.8368	0.68224	17.8432	0.02624
42	1123.20	459.26	24.9600	0.42432	0.37440	2.1216	0.67392	23.7120	0.02496
43	2050.65	58.59	16.6005	2.89695	0.03255	0.9114	0.61845	10.0905	0.03255
44	1626.57	6.14	11.0484	2.48589	0.06138	0.2148	0.42966	8.5932	0.03069
45	1654.13	21.85	10.6114	3.43310	0.03121	1.1548	0.65541	11.8598	0.03121

ORIGINAL VEGETATION (DRY WEIGHT) AND SOIL DATA

OBS	INDIV	GROUP	SPECIES	REGION	LOCAL	PB210	PO210	RA226	URANIUM	BORON	PHOSPHOR	SILVER	ALUMINUM
46	34	2	4	2	3	0.01	0.01	0.0048272	0.01207	3.9221	1478.33	0.006034	193.088
47	35	2	4	2	3	0.04	0.02	0.0050472	0.01402	6.1688	1514.16	0.005608	182.260
48	36	2	4	2	3	0.04	0.02	0.0082320	0.01098	2.7440	1289.68	0.005488	186.592
49	37	2	4	2	4	0.02	0.01	0.0075025	0.00600	3.0010	1638.55	0.030010	138.046
50	38	2	4	2	4	0.04	0.02	0.0111930	0.01279	3.8376	1260.01	0.038376	147.108
51	39	2	4	2	4	0.04	0.02	0.0148800	0.02381	5.3568	993.98	0.059520	83.328
52	40	2	5	1	1	0.05	0.03	0.0089190	0.24676	7.4325	942.44	0.101082	118.920
53	41	2	5	1	1	0.13	0.07	0.0022572	0.23074	6.7716	955.55	0.188100	127.908
54	42	2	5	1	1	0.05	0.03	0.0043826	0.18046	10.3120	1090.49	0.183038	90.230

OBS	BERYL	CALCIUM	CADMIUM	COBALT	CHROMIUM	COPPER	IRON	POTASS
46	0.090510	3318.70	0.009051	1.35765	0.42238	8.14590	108.612	2413.6
47	0.103748	2663.80	0.019628	0.78512	0.42060	6.16880	95.336	2327.3
48	0.063112	2387.28	0.005488	0.09055	0.20854	6.58560	85.064	1289.6
49	0.036012	4261.42	0.030010	0.63021	0.39013	5.40180	75.025	5851.9
50	0.038376	5180.76	0.031980	1.72692	0.51168	3.83760	76.752	5148.7
51	0.041664	3422.40	0.029760	0.65472	0.68448	4.46400	59.520	4583.0
52	0.014865	6362.22	0.053514	0.01487	0.32703	4.16220	32.703	3924.3
53	0.012540	4614.72	0.025080	0.02006	0.27588	4.26360	20.064	3511.2
54	0.012890	4511.50	0.033514	0.02062	0.30936	5.67160	23.202	2887.3

OBS	MAGNES	MANGAN	SODIUM	NICKEL	LEAD	TITANIUM	VANADIUM	ZINC	TRANSF
46	2051.56	60.34	36.204	4.52550	0.030[illegible]	4.2238	0.78442	10.8612	0.03017
47	1542.20	92.53	24.114	3.36480	0.028[illegible]	3.6452	0.81316	21.8712	0.02804
48	1646.40	54.88	18.934	3.01840	0.02744	0.5762	0.65856	12.0736	0.02744
49	1620.54	120.04	28.209	3.00100	0.12004	2.2808	0.48016	22.5075	0.03001
50	1874.03	95.94	17.909	3.51780	0.12792	2.6863	0.63960	8.9544	0.03198
51	1279.68	127.97	16.070	2.97600	0.35712	1.7558	0.59520	22.0224	0.02976
52	1067.31	832.44	17.243	0.83244	0.05946	0.0892	0.59460	24.0813	0.02973
53	1028.28	1166.22	17.556	0.27588	0.05016	0.0251	0.62700	20.3148	0.02508
54	992.53	989.95	12.632	0.28358	0.05156	0.0258	0.59294	23.9754	0.02578

ORIGINAL VEGETATION (DRY WEIGHT) AND SOIL DATA

OBS	INDIV	GROUP	SPECIES	REGION	LOCAL	PB210	PO210	RA226	URANIUM	BORON	PHOSPHOR	SILVER
55	43	2	5	1	2	0.04	0.03	0.0080040	0.19743	6.13640	933.80	0.098716
56	44	2	5	1	2	0.06	0.04	0.0129480	0.35607	5.82660	809.25	0.145665
57	45	2	5	1	2	0.04	0.03	0.0139360	0.31704	9.05840	1080.04	0.181168
58	46	2	5	2	3	0.05	0.03	0.0195160	0.02230	5.29720	697.00	0.133824
59	47	2	5	2	3	0.09	0.06	0.0169950	0.01236	4.32600	710.70	0.098880
60	48	2	5	2	3	0.10	0.06	0.0126675	0.01971	5.91150	731.90	0.123860
61	49	2	5	2	4	0.05	0.04	0.0888800	0.01111	9.11020	822.14	0.135542
62	50	2	5	2	4	0.05	0.04	0.0508000	0.01270	8.89000	944.88	0.116840
63	51	2	5	2	4	0.08	0.06	0.0476200	0.00952	7.85730	785.73	0.142860

OBS	ALUMINUM	BERYLL	CALCIUM	CADMIUM	COBALT	CHROMIUM	COPPER	IRON	POTASS
55	96.0	0.00534	4802.40	0.008004	0.02401	0.1921	3.2016	32.0	1867.6
56	178.0	0.00647	8416.20	0.022659	0.04208	0.2590	3.8844	45.3	2783.8
57	135.9	0.00697	7664.80	0.024388	0.02787	0.2857	4.1808	45.3	2229.7
58	223.0	0.00836	5576.00	0.133824	0.02788	0.2788	3.6244	69.7	1143.0
59	154.5	0.00927	6489.00	0.071070	0.03090	0.2596	3.7080	61.8	1050.6
60	163.3	0.00563	5067.00	0.084450	0.03941	0.2421	3.9410	56.3	1632.7
61	122.2	0.01111	4377.34	0.053328	0.04444	0.4222	3.5552	44.4	2533.0
62	109.2	0.01270	4978.40	0.093980	0.06604	0.3302	4.0640	45.7	2565.4
63	102.4	0.01191	4881.05	0.057144	0.05714	0.3333	4.0477	35.7	3404.8

OBS	MAGNES	MANGAN	SODIUM	NICKEL	LEAD	TITANIUM	VANADIUM	ZINC	TRANSF
55	960.48	800.40	14.407	0.3735	0.02668	0.56	0.4536	12.5396	0.02668
56	1262.43	1003.47	11.653	0.3884	0.03237	1.04	0.7121	13.5954	0.03237
57	1393.60	1323.92	38.324	0.6271	0.03484	0.87	0.8362	19.5104	0.03484
58	1143.08	864.28	27.322	0.3346	0.02788	1.06	0.6970	21.4676	0.02788
59	1236.00	741.60	26.265	0.5253	0.03090	0.46	0.6798	21.3210	0.03090
60	1041.55	844.50	25.898	0.3941	0.02815	0.87	0.7601	18.5790	0.02815
61	1253.21	742.15	15.998	1.1554	0.04444	0.64	0.7110	22.2200	0.02222
62	1328.42	756.92	21.082	0.7620	0.05080	1.40	0.7366	23.8760	0.02540
63	1207.17	714.30	18.810	1.0238	0.04762	0.33	0.5476	23.8100	0.02381

ORIGINAL VEGETATION (DRY WEIGHT) AND SOIL DATA

OBS	INDIV	GROUP	SPECIES	REGION	LOCAL	PB210	PO210	RA226	URANIUM	BORON	PHOSPHOR	SILVER	
64	88	3	0	1	1	0.50	0.45	0.004484	3.2173	0.13452	358.72	0.002242	381.
65	89	3	0	1	1	0.50	0.45	0.004939	2.7569	0.27838	323.28	0.001796	287.
66	90	3	0	1	1	0.40	0.25	0.003608	2.5887	0.19844	423.94	0.007216	243.
67	91	3	0	1	2	0.50	0.35	0.003108	1.8285	0.20202	155.40	0.001036	139.
68	92	3	0	1	2	0.50	0.30	0.006643	3.5872	0.19418	296.38	0.002044	347.
69	93	3	0	1	2	0.50	0.35	0.003400	1.8148	0.07845	167.36	0.001046	172.
70	94	3	0	2	3	0.50	0.40	0.001295	0.0229	0.05334	182.88	0.001524	274.
71	95	3	0	2	3	0.45	0.30	0.001054	0.0186	0.08680	161.20	0.001240	192.
72	96	3	0	2	3	0.45	0.30	0.001246	0.0193	0.07476	180.67	0.002492	205.

OBS	BERYLL	CALCIUM	CADMIUM	COBALT	CHROMIUM	COPPER	IRON	POTASS	
64	0.06166	381.14	0.156940	0.09080	0.4708	0.8071	145.7	627.76	168.1
65	0.05029	323.28	0.125720	0.07184	0.4670	0.6915	152.7	449.00	143.6
66	0.03969	351.78	0.126280	0.07396	0.3518	0.7126	64.9	505.12	180.4
67	0.02797	170.94	0.082880	0.04351	0.2797	0.4766	82.9	569.80	88.0
68	0.06745	327.04	0.122640	0.11242	2.8616	0.7665	194.2	756.28	183.9
69	0.03190	193.51	0.083680	0.05125	0.2354	0.4079	68.0	266.73	99.3
70	0.05410	160.02	0.236220	0.09144	0.3810	0.6248	182.9	594.36	114.3
71	0.04278	155.00	0.155000	0.06820	0.4340	0.5828	130.2	502.20	93.0
72	0.04174	161.98	0.186900	0.06230	0.4299	0.6230	124.6	442.33	99.6

OBS	MANGAN	SODIUM	NICKEL	LEAD	TITANIUM	VANADIUM	ZINC	TRANSF
64	36.993	31.388	0.4148	1.56940	8.07	0.9192	15.6940	0.01121
65	48.492	26.940	0.3682	1.34700	5.84	0.7364	12.5720	0.00898
66	55.022	27.962	0.3698	1.08240	4.78	0.6585	9.9220	0.00902
67	12.432	17.612	0.3108	1.03600	4.87	0.4299	6.2160	0.00518
68	25.550	52.122	1.9418	1.22640	9.40	0.9709	12.2640	0.01022
69	13.075	18.305	0.2772	0.62760	5.07	0.4602	6.7990	0.00523
70	9.906	19.050	0.2972	1.98120	7.62	0.7010	10.6680	0.00762
71	12.400	19.840	0.5146	1.48800	1.92	0.5766	9.3000	0.00620
72	11.214	22.428	0.8099	1.18370	1.93	0.5794	9.9680	0.00623

ORIGINAL VEGETATION (DRY WEIGHT) AND SOIL DATA

OBS	INDIV	GROUP	SPECIES	REGION	LOCAL	PB210	PO210	RA226	URANIUM	BORON	PHOSPHOR	SILVER	
73	97	3	0	2	4	0.45	0.35	0.002563	0.0318	0.27675	451.00	0.002050	297.
74	98	3	0	2	4	0.50	0.30	0.002538	0.0396	0.17255	416.15	0.002030	345.
75	99	3	0	2	4	0.35	0.30	0.002443	0.0303	0.19540	527.58	0.001954	293.
76	64	3	7	2	3	0.40	0.20	0.003215	0.0412	0.27006	643.00	0.002572	347.
77	65	3	7	2	3	0.30	0.25	0.002480	0.0365	0.26100	678.60	0.002610	339.
78	66	3	7	2	3	0.40	0.30	0.001416	0.0307	0.27140	542.80	0.002360	247.
79	67	3	7	2	4	0.30	0.18	0.005841	0.0340	0.37170	637.20	0.004248	233.
80	68	3	7	2	4	0.40	0.20	0.002194	0.0351	0.38395	625.29	0.006582	318.
81	69	3	7	2	4	0.30	0.16	0.003987	0.0308	0.34170	763.13	0.002278	273.

OBS	BERYLL	CALCIUM	CADMIUM	COBALT	CHROMIUM	COPPER	IRON	POTASS	
73	0.06253	307.50	0.246000	0.12300	0.5945	1.0148	194.8	481.75	194.7
74	0.06598	314.65	0.284200	0.11165	0.6090	1.0556	203.0	609.00	203.0
75	0.05569	381.03	0.214940	0.10747	0.4885	1.1724	185.6	439.65	234.4
76	0.08102	437.24	0.347220	0.15432	0.6044	1.1960	257.2	951.64	257.2
77	0.07700	456.75	0.365400	0.16965	0.7961	1.2267	248.0	1305.00	287.1
78	0.05074	377.60	0.247800	0.11682	0.5782	1.2980	188.8	708.00	224.2
79	0.05522	446.04	0.201780	0.12744	0.6053	1.3806	127.4	594.72	297.3
80	0.06034	449.77	0.263280	0.13164	0.6363	1.3164	164.6	680.14	252.3
81	0.05353	535.33	0.227800	0.12529	0.5923	1.5946	148.1	694.79	307.5

OBS	MANGAN	SODIUM	NICKEL	LEAD	TITANIUM	VANADIUM	ZINC	TRANSF
73	35.875	50.225	0.3793	1.74250	8.00	0.8610	16.4000	0.01025
74	22.330	52.780	0.5684	1.92850	3.55	0.9440	16.2400	0.01015
75	39.080	53.735	0.3713	1.56320	9.28	0.8011	15.6320	0.00977
76	46.296	61.728	0.8102	1.92900	12.86	1.1060	25.7200	0.01286
77	44.370	57.420	1.4355	1.56600	4.70	1.0832	26.1000	0.01305
78	36.580	62.540	0.4484	1.18000	7.55	0.7788	18.8800	0.01180
79	63.720	55.224	0.5098	0.79650	9.88	0.8815	21.2400	0.01062
80	32.910	66.917	0.7240	0.86663	12.07	0.9434	19.7460	0.01097
81	68.340	70.618	0.4214	0.86564	9.00	0.8884	18.2240	0.01139

ORIGINAL VEGETATION (DRY WEIGHT) AND SOIL DATA

OBS	INDIV	GROUP	SPECIES	REGION	LOCAL	PB210	PO210	RA226	URANIUM	BORON	PHOSPHOR	SILVER	
82	70	3	8	1	1	0.30	0.20	0.002575	2.0188	0.41200	509.85	0.010300	236.
83	71	3	8	1	1	0.35	0.25	0.007806	3.1484	0.44234	628.38	0.013010	340.
84	72	3	8	1	1	0.35	0.25	0.006516	2.4001	0.65160	683.09	0.010860	211.
85	73	3	8	1	2	0.45	0.35	0.009648	3.5698	0.20368	463.10	0.005360	300.
86	74	3	8	1	2	0.45	0.25	0.008820	3.1458	0.25480	471.38	0.009800	244.
87	75	3	8	1	2	0.40	0.30	0.010190	3.4544	0.39741	413.71	0.010190	270.
88	76	4	9	1	1	0.45	0.45	0.005486	2.6881	1.26178	1163.03	0.030173	310.
89	77	4	9	1	1	0.40	0.35	0.004946	2.1021	0.93974	1206.82	0.012365	254.
90	78	4	9	1	1	0.45	0.25	0.007320	2.8109	1.17120	1343.95	0.014640	322.

OBS	BERYLL	CALCIUM	CADMIUM	COBALT	CHROMIUM	COPPER	IRON	POTASS	
82	0.02472	556.20	0.092700	0.05768	0.3605	0.6077	124.6	1452.30	243.0
83	0.03903	663.51	0.114488	0.08326	0.4814	0.7806	175.6	1691.30	268.0
84	0.02389	564.72	0.108600	0.05864	0.4127	0.6516	118.4	1911.36	301.9
85	0.03430	493.12	0.105056	0.08362	0.4181	0.5896	200.5	1372.16	236.9
86	0.02940	460.60	0.117600	0.07840	0.4116	0.5488	134.3	1528.80	224.4
87	0.03261	478.93	0.101900	0.07744	0.3668	0.5503	159.0	1365.46	239.4
88	0.04663	2523.56	0.329160	0.17555	0.8229	3.0173	214.0	3456.18	1157.5
89	0.04204	2126.78	0.202786	0.09892	0.7172	2.7203	200.3	4451.40	1117.8
90	0.03806	2957.28	0.196176	0.07613	0.5563	2.7816	187.4	4626.24	936.9

OBS	MANGAN	SODIUM	NICKEL	LEAD	TITANIUM	VANADIUM	ZINC	TRANSF
82	21.630	33.990	0.3708	0.22660	4.53	0.5768	10.3000	0.01030
83	91.070	49.438	0.4554	0.57244	6.37	0.7806	18.2140	0.01301
84	70.590	36.924	0.6625	0.54300	4.02	0.5647	14.1180	0.01086
85	27.872	32.160	0.4931	0.42880	5.15	0.6754	11.7920	0.01072
86	23.520	33.320	0.8624	0.62720	5.10	0.6468	11.7600	0.00980
87	29.551	32.608	0.3770	0.48912	5.40	0.6318	11.2090	0.01019
88	257.842	74.061	0.7132	1.89267	3.84	1.3989	21.3954	0.02743
89	321.490	61.825	0.6677	1.43434	3.96	1.6075	24.7300	0.02473
90	488.976	67.344	0.6442	1.02480	6.44	1.4347	38.0640	0.02928

ORIGINAL VEGETATION (DRY WEIGHT) AND SOIL DATA

OBS	INDIV	GROUP	SPECIES	REGION	LOCAL	PB210	PO210	RA226	URANIUM	BORON	PHOSPHOR	SILVER	
91	79	4	9	1	2	0.90	0.45	0.009360	3.1616	1.20640	717.60	0.031200	330.
92	80	4	9	1	2	0.60	0.45	0.007476	3.5030	2.13600	608.76	0.017088	316.
93	81	4	9	1	2	0.50	0.40	0.011760	4.1630	1.05840	766.75	0.014112	355.
94	82	4	9	2	3	0.55	0.35	0.005681	0.0836	1.00260	1236.54	0.016710	554.
95	83	4	9	2	3	0.55	0.40	0.003947	0.0789	1.18404	1216.93	0.016445	559.
96	84	4	9	2	3	0.60	0.25	0.003220	0.0563	0.72441	1043.69	0.013415	477.
97	85	4	9	2	4	0.45	0.30	0.015575	0.0356	0.46725	961.20	0.011125	313.
98	86	4	9	2	4	0.55	0.35	0.005434	0.0625	0.97812	1296.01	0.013585	470.
99	87	4	9	2	4	0.50	0.40	0.011792	0.0708	0.82544	1329.55	0.014740	554.

OBS	BERYL	CALCIUM	CADMIUM	COBALT	CHROMIUM	COPPER	IRON	POTASS	
91	0.04160	1851.20	0.139360	0.11440	0.5200	2.4960	203.8	4180.80	688.4
92	0.05554	1836.96	0.160200	0.12389	0.5767	2.5632	222.1	3161.28	638.6
93	0.05174	2046.24	0.169344	0.09878	0.3293	2.8224	195.2	4539.36	787.9
94	0.10360	2840.70	0.467880	0.33420	1.5039	4.3446	487.9	4946.16	1119.5
95	0.10525	3124.55	0.427570	0.32232	1.4472	4.9335	483.5	4473.04	930.7
96	0.08049	2441.53	0.482940	0.24684	1.1000	3.2196	364.9	4453.78	826.3
97	0.04673	1869.00	0.195800	0.14463	0.5340	2.8925	253.6	3916.00	763.1
98	0.06793	2363.79	0.271700	0.27170	0.8151	3.5321	358.6	3369.08	1081.3
99	0.08254	2653.20	0.324280	0.29185	0.7665	2.9480	436.3	5188.48	1025.9

OBS	MANGAN	SODIUM	NICKEL	LEAD	TITANIUM	VANADIUM	ZINC	TRANSF
91	122.720	74.880	0.5408	1.45600	11.02	1.0816	14.1440	0.02080
92	158.064	64.080	0.5981	1.68744	2.99	1.1962	18.7968	0.02136
93	157.584	72.912	0.5880	0.04704	1.08	1.0349	18.1104	0.02352
94	290.754	126.996	1.2031	1.70442	7.69	2.3394	40.1040	0.03342
95	411.125	121.693	1.1512	1.97340	7.24	2.4010	46.0460	0.03289
96	311.228	85.856	0.9391	0.59026	4.83	2.0122	42.9280	0.02683
97	287.025	66.750	0.6898	0.11125	4.45	1.2460	26.7000	0.02225
98	285.285	92.378	0.8694	1.71171	5.98	1.7661	27.1700	0.02717
99	347.864	94.336	0.9139	0.47168	8.84	2.0046	44.2200	0.02948

ORIGINAL VEGETATION (DRY WEIGHT) AND SOIL DATA

OBS	INDIV	GROUP	SPECIES	REGION	LOCAL	PB210	PO210	RA226	URANIUM	BORON	PHOSPHOR	SILVER	ALUMINUM	BERYLL	
100	100	5	11	1	1	0.02	0.02	0.03	0.8	5	100	0.5	3100	0.9	
101	101	5	11	1	1	0.02	0.01	0.03	0.8	5	100	0.5	3900	0.8	
102	102	5	11	1	1	0.03	0.03	0.07	1.1	5	200	0.5	9100	1.9	
103	103	5	11	1	2	0.02	0.02	0.08	1.9	5	300	0.5	11000	2.9	10(
104	104	5	11	1	2	0.02	0.02	0.06	1.8	5	100	0.5	9100	1.9	10(
105	105	5	11	1	2	0.02	0.02	0.05	1.8	5	200	0.5	5700	1.0	10(
106	106	5	11	2	3	0.07	0.09	0.02	1.9	5	300	0.5	7600	1.8	
107	107	5	11	2	3	0.04	0.04	0.05	3.6	5	100	0.5	3300	0.9	
108	108	5	11	2	3	0.10	0.09	0.08	3.6	5	1100	0.5	18000	2.4	
109	109	5	11	2	4	0.18	0.20	0.30	5.8	5	700	0.5	7600	1.3	10(
110	110	5	11	2	4	0.15	0.17	0.25	7.7	5	700	0.5	11000	1.6	10(
111	111	5	11	2	4	0.16	0.20	0.30	17.3	5	500	0.5	10000	1.4	

OBS	CADMIUM	COBALT	CHROMIUM	COPPER	IRON	POTASS	MAGNES	MANGAN	SODIUM	NICKEL	LEAD	TITANIUM	VANADIUM	ZINC	TRANSF
100	0.5	0.7	68.0	2	3400	1000	300	0	130	5	2	78	6	0	1
101	0.5	0.9	57.0	1	2800	1000	700	100	110	12	2	100	6	10	1
102	0.5	1.8	41.0	1	6400	1000	1200	0	100	11	2	250	13	10	1
103	0.5	2.4	12.0	1	11000	1000	1400	0	100	5	2	690	26	10	1
104	0.5	1.7	14.0	1	6500	1000	1300	0	90	5	2	490	16	10	1
105	0.5	2.1	9.9	2	3400	0	600	0	110	7	2	650	12	0	1
106	0.5	0.8	30.0	4	5500	1000	400	100	130	3	2	350	9	20	1
107	0.5	0.5	66.0	2	3000	0	200	400	200	2	2	150	5	20	1
108	0.5	2.9	25.0	32	7300	1000	800	0	160	6	3	1100	27	20	1
109	0.5	0.9	58.0	9	3900	2000	500	100	180	10	3	250	9	40	1
110	0.5	1.7	39.0	19	4800	2000	600	0	240	6	2	420	14	60	1
111	0.5	1.4	52.0	19	4200	1000	500	0	130	8	2	250	12	30	1

APPENDIX II

Summaries of distribution of non-radioactive elements (ICP analysis) by locality, region, species and species group. Elements are arranged in alphabetical order.

Species and species group codes are as follows:

SPECIES	GROUP = Species Group
0) *Cladina stellaris* (Opiz.) Brodo	3) Lichen
1) *Vaccinium myrtilloides* Michx.	2) Shrub
2) *Pinus banksiana* Lamb.	1) Tree
3) *Ledum groenlandicum* Oeder.	2) Shrub
4) *Alnus crispa* (Ait.) Pursh.	2) Shrub
5) *Vaccinium vitis-idaea* L.	2) Shrub
6) *Picea mariana* (Mill.) BSP	1) Tree
7) *Cladina rangiferina* (L.) Harm.	3) Lichen
8) *C. mitis* (Sandst.) Hale & W. Culb.	3) Lichen
9) *Pleurozium schreberi* (Brid.) Mitt.	4) Moss
11) Soil	5) Soil

Units of Measurement.

Pb^{210}, Po^{210} Bq/g dry wt.

Ra^{226} Bq/g dry wt.

Uranium-Zinc ug/g dry wt.

Transf - % ash wt.

SUMMARY TABLE OF MEANS (DRY WEIGHT) BY LOCALITY AND SPECIES.

MEAN OF ALUMINUM (x 0.1)

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	38.346	.	31.181	.	34.764	14.944
	6	4.227	5.102	6.638	4.173	5.035	
2	1	16.592	17.151	18.674	17.082	17.375	
	3	6.112	6.893	9.466	7.286	7.439	
	4	.	21.632	18.731	12.283	17.549	13.730
	5	11.235	13.665	18.027	11.127	13.514	
3	0	30.401	21.998	22.404	31.182	26.496	
	7	.	.	31.144	27.504	29.324	27.261
	8	26.318	27.141	.	.	26.729	
4	9	29.559	33.400	53.049	44.600	40.152	40.152
5	11	5.367	8.600	9.633	9.533	8.283	8.283
. LOCALITIES		18.684	17.287	21.895	18.308	19.120	
REGIONS		17.986		20.196			

SUMMARY TABLE OF MEANS (DRY WEIGHT) BY LOCALITY AND SPECIES.

MEAN OF BERYLL (x 100)

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	2.260	.	1.770	.	2.015	1.768
	6	1.751	1.896	1.772	1.159	1.644	
2	1	0.626	1.257	2.443	1.132	1.364	
	3	1.977	2.322	2.434	1.649	2.096	
	4	.	5.688	8.579	3.868	6.045	2.394
	5	1.343	0.626	0.775	1.190	0.984	
3	0	5.054	4.244	4.621	6.140	5.015	
	7	.	.	6.958	5.636	6.297	4.484
	8	2.921	3.210	.	.	3.066	
4	9	4.225	4.963	9.645	6.573	6.351	6.351
5	11	1.200	1.933	1.700	1.433	1.567	1.567
.	LOCALITIES	2.373	2.904	4.070	3.198	3.162	
	REGIONS	2.639		3.657			

SUMMARY TABLE OF MEANS (DRY WEIGHT) BY LOCALITY AND SPECIES.

MEAN OF BORON (x 100)

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	928.460	.	677.647	.	803.053	629.053
	6	951.057	428.630	402.200	386.323	542.053	
2	1	993.740	503.313	914.327	1184.163	898.886	
	3	1518.283	949.527	1047.910	921.293	1109.253	
	4	.	764.753	427.830	406.513	533.032	835.287
	5	817.203	700.713	517.823	861.917	724.414	
3	0	20.378	15.822	7.163	21.490	16.213	
	7	.	.	26.749	36.578	31.664	25.863
	8	50.198	28.530	.	.	39.364	
4	9	112.424	146.693	97.035	75.694	107.962	107.962
5	11	5.000	5.000	5.000	5.000	5.000	5.000
. LOCALITIES		599.638	393.665	412.368	433.219	458.443	
REGIONS		496.651		422.245			

SUMMARY TABLE OF MEANS (DRY WEIGHT) BY LOCALITY AND SPECIES.

MEAN OF CADMIUM (x 100)

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	19.401	.	19.609	.	19.505	7.980
	6	2.698	1.896	2.251	2.023	2.217	
2	1	5.613	2.212	3.579	2.885	3.572	
	3	4.048	2.322	3.644	2.153	3.042	
	4	.	1.039	1.139	3.058	1.745	3.582
	5	3.737	1.835	9.645	6.815	5.508	
3	0	13.631	9.640	19.271	24.838	16.845	
	7	.	.	32.014	23.095	27.555	17.979
	8	10.526	10.819	.	.	10.672	
4	9	24.271	15.630	45.946	26.393	28.060	28.060
5	11	0.500	0.500	0.500	0.500	0.500	0.500
. LOCALITIES		9.381	5.099	13.760	10.196	9.721	
REGIONS		7.240		12.072			

SUMMARY TABLE OF MEANS (DRY WEIGHT) BY LOCALITY AND SPECIES.

MEAN OF CALCIUM (x 0.1)

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	367.340	.	279.216	.	323.278	392.630
	6	491.988	453.348	359.368	404.517	427.305	
2	1	477.790	487.833	664.110	534.447	541.045	
	3	602.660	637.725	580.941	517.187	584.628	
	4	.	356.720	278.993	428.819	354.844	521.683
	5	516.281	696.113	571.067	474.560	564.505	
3	0	35.207	23.050	15.900	33.439	26.899	
	7	.	.	42.386	47.705	45.045	38.115
	8	59.481	47.755	.	.	53.618	
4	9	253.587	191.147	280.226	229.533	238.623	238.623
5	11	0.000	1.000	0.000	0.667	0.417	0.417
.	LOCALITIES	311.593	321.632	307.221	296.764	309.246	
	REGIONS	316.612		302.267			

SUMMARY TABLE OF MEANS (DRY WEIGHT) BY LOCALITY AND SPECIES.

MEAN OF CHROMIUM (x 100)

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	72.574	.	66.402	.	69.488	42.900
	6	34.713	23.228	21.751	38.733	29.606	
2	1	45.202	31.042	41.061	37.710	38.754	
	3	37.477	22.531	43.744	29.996	33.437	
	4	.	21.038	35.051	52.876	36.322	34.327
	5	30.409	24.558	26.015	36.191	29.293	
3	0	42.985	112.556	41.496	56.400	63.359	
	7	.	.	65.956	61.129	63.543	57.778
	8	41.818	39.884	.	.	40.851	
4	9	69.880	47.533	135.036	70.519	80.742	80.742
5	11	55.333	11.967	40.333	49.667	39.325	39.325
.	LOCALITIES	47.821	37.148	51.684	48.136	46.346	
	REGIONS		42.485		50.004		

SUMMARY TABLE OF MEANS (DRY WEIGHT) BY LOCALITY AND SPECIES.

MEAN OF COBALT (x 100)

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	10.119	.	4.848	.	7.483	4.610
	6	2.409	1.896	4.414	3.974	3.173	
2	1	2.888	4.792	15.724	7.740	7.786	
	3	3.300	2.322	10.656	6.661	5.735	
	4	.	74.624	74.444	100.395	83.154	21.159
	5	1.852	3.132	3.273	5.587	3.461	
3	0	7.887	6.906	7.398	11.404	8.399	
	7	.	.	14.693	12.812	13.753	9.467
	8	6.653	7.982	.	.	7.317	
4	9	11.687	11.236	30.112	23.606	19.160	19.160
5	11	1.133	2.067	1.400	1.333	1.483	1.483
.	LOCALITIES	5.325	12.773	16.696	19.279	13.604	
	REGIONS	9.049		17.920			

SUMMARY TABLE OF MEANS (DRY WEIGHT) BY LOCALITY AND SPECIES.

MEAN OF COPPER

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	2.094	.	3.437	.	2.766	2.325
	6	2.569	1.606	1.810	2.436	2.105	
2	1	4.620	5.264	7.291	5.204	5.595	
	3	5.284	4.094	4.945	4.008	4.582	
	4	.	4.085	6.967	4.568	5.206	4.829
	5	4.699	3.756	3.758	3.889	4.025	
3	0	0.737	0.550	0.610	1.081	0.745	
	7	.	.	1.240	1.431	1.335	0.862
	8	0.680	0.563	.	.	0.621	
4	9	2.840	2.627	4.166	3.124	3.189	3.189
5	11	0.013	0.013	0.127	0.157	0.078	7.750
. LOCALITIES		2.615	2.506	3.435	2.878	2.874	

REGIONS 0.256 0.317

SUMMARY TABLE OF MEANS (DRY WEIGHT) BY LOCALITY AND SPECIES.

MEAN OF IRON (x 0.1)

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	5.697	.	5.033	.	5.365	3.655
	6	2.092	2.930	3.322	2.857	2.800	
2	1	7.665	8.336	13.129	9.537	9.667	
	3	4.957	3.632	7.540	6.173	5.576	
	4	.	6.657	9.634	7.043	7.778	6.759
	5	2.532	4.088	6.260	4.196	4.269	
3	0	12.111	11.502	14.589	19.446	14.412	
	7	.	.	23.132	14.669	18.900	15.732
	8	13.955	16.456	.	.	15.205	
4	9	20.055	20.707	44.543	34.953	30.065	30.065
5	11	4.200	6.967	5.267	4.300	5.183	5.183
.	LOCALITIES	8.141	9.030	13.245	11.464	10.545	
	REGIONS		8.586		12.401		

SUMMARY TABLE OF MEANS (DRY WEIGHT) BY LOCALITY AND SPECIES.

MEAN OF LEAD (x 100)

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	4.676	.	6.609	.	5.642	7.830
	6	7.825	13.489	9.741	4.637	8.923	
2	1	3.128	2.878	5.603	3.078	3.672	
	3	9.889	9.290	31.178	17.413	16.943	
	4	.	4.171	2.855	20.169	9.065	8.388
	5	5.373	3.130	2.898	4.762	4.041	
3	0	133.293	96.333	155.097	174.473	139.799	
	7	.	.	155.833	84.292	120.063	111.945
	8	44.735	51.504	.	.	48.119	
4	9	145.060	106.349	142.269	76.488	117.542	117.542
5	11	2.000	2.000	2.333	2.333	2.167	2.167
.	LOCALITIES	39.553	32.127	51.442	43.072	41.816	
	REGIONS	35.840		47.477			

SUMMARY TABLE OF MEANS (DRY WEIGHT) BY LOCALITY AND SPECIES.

MEAN OF MAGNES (x 0.1)

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	74.996	.	77.736	.	76.366	90.049
	6	91.175	95.879	97.533	102.978	96.891	
2	1	126.941	182.237	185.603	164.635	164.854	
	3	132.188	96.111	122.457	123.956	118.678	
	4	.	177.712	174.672	159.142	170.508	140.630
	5	102.937	120.550	114.021	126.293	115.950	
3	0	16.408	12.380	10.233	21.074	15.024	
	7	.	.	25.617	28.573	27.095	20.593
	8	27.100	23.360	.	.	25.230	
4	9	107.077	70.502	95.891	95.682	92.288	92.288
5	11	0.733	1.100	0.467	0.533	0.708	0.708
. LOCALITIES		75.506	86.648	90.423	91.430	86.121	
REGIONS		81.077		90.900			

SUMMARY TABLE OF MEANS (DRY WEIGHT) BY LOCALITY AND SPECIES.

MEAN OF MANGAN (x 0.1)

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	61.031	.	33.069	.	47.050	48.100
	6	93.734	25.553	31.834	43.379	48.625	
2	1	333.877	66.257	76.084	123.534	149.938	
	3	55.738	27.526	64.475	49.321	49.265	
	4	.	2.886	6.925	11.465	7.092	78.495
	5	99.620	104.260	81.679	73.779	89.835	
3	0	4.684	1.702	1.117	3.243	2.686	
	7	.	.	4.242	5.499	4.870	3.662
	8	6.110	2.698	.	.	4.404	
4	9	35.610	14.612	33.770	30.672	28.666	28.666
5	11	0.033	0.000	0.167	0.033	0.058	0.058
.	LOCALITIES	76.715	27.277	33.336	37.881	43.519	

REGIONS 51.996 35.489

SUMMARY TABLE OF MEANS (DRY WEIGHT) BY LOCALITY AND SPECIES.

MEAN OF NICKEL (x 100)

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	174.507	.	139.264	.	156.885	105.494
	6	52.159	57.827	64.837	144.371	79.798	
2	1	99.821	157.282	209.742	127.773	148.654	
	3	113.202	117.565	123.763	77.463	107.998	
	4	.	293.865	363.623	316.493	324.660	148.875
	5	46.397	46.303	41.799	98.042	58.135	
3	0	38.426	84.326	54.056	43.964	55.193	
	7	.	.	89.803	55.174	72.488	59.140
	8	49.620	57.752	.	.	53.686	
4	9	67.502	57.563	109.777	82.436	79.319	79.319
5	11	9.333	5.667	3.667	8.000	6.667	6.667
. LOCALITIES		72.330	97.572	120.033	105.968	99.545	
REGIONS		84.951		113.371			

SUMMARY TABLE OF MEANS (DRY WEIGHT) BY LOCALITY AND SPECIES.

MEAN OF PHOSPHOR (x 0.1)

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	88.361	.	74.080	.	81.220	97.181
	6	128.235	89.873	85.169	117.369	105.161	
2	1	104.496	108.839	83.748	101.153	99.559	
	3	82.761	116.018	112.648	107.601	104.757	
	4	.	194.650	142.739	129.751	155.713	108.969
	5	99.616	94.103	71.320	85.092	87.533	
3	0	36.865	20.638	17.492	46.491	30.371	
	7	.	.	62.147	67.521	64.834	44.600
	8	60.711	44.940	.	.	52.825	
4	9	123.794	69.770	116.572	119.559	107.424	107.424
5	11	0.133	0.200	0.500	0.633	0.367	0.367
.	LOCALITIES	80.552	82.115	76.641	86.130	81.232	
	REGIONS	81.333		81.136			

SUMMARY TABLE OF MEANS (DRY WEIGHT) BY LOCALITY AND SPECIES.

MEAN OF POTASS (x 0.1)

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	312.337	.	240.475	.	276.406	337.091
	6	355.359	412.965	321.453	379.957	367.434	
2	1	96.386	209.644	156.820	85.979	137.207	
	3	431.305	511.877	472.229	277.108	423.130	
	4	.	292.023	201.020	519.459	337.501	282.554
	5	344.097	229.373	127.546	283.444	246.115	
3	0	52.729	53.094	51.296	51.013	52.033	
	7	.	.	98.821	65.655	82.238	85.415
	8	168.499	142.214	.	.	155.356	
4	9	417.794	396.048	462.433	415.785	423.015	423.015
5	11	1.000	0.667	0.667	1.667	1.000	1.000
• LOCALITIES		242.167	249.767	213.276	231.119	233.520	
REGIONS		245.967		221.728			

SUMMARY TABLE OF MEANS (DRY WEIGHT) BY LOCALITY AND SPECIES.

MEAN OF SILVER (x 100)

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	11.674	.	5.908	.	8.791	7.391
	6	11.596	3.565	7.308	4.294	6.691	
2	1	49.902	5.594	10.291	16.870	20.664	
	3	8.253	3.806	9.637	8.835	7.633	
	4	.	0.847	0.571	4.264	1.894	11.590
	5	15.741	14.185	11.885	13.175	13.746	
3	0	0.375	0.138	0.175	0.201	0.222	
	7	.	.	0.251	0.437	0.344	0.445
	8	1.139	0.845	.	.	0.992	
4	9	1.906	2.080	1.552	1.315	1.713	1.713
5	11	0.500	0.500	0.500	0.500	0.500	0.500
. LOCALITIES		11.232	3.507	4.808	5.543	6.233	
REGIONS		7.369		5.156			

SUMMARY TABLE OF MEANS (DRY WEIGHT) BY LOCALITY AND SPECIES.

MEAN OF SODIUM (x 0.1)

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	1.537	.	1.931	.	1.734	1.310
	6	1.018	1.047	1.238	1.089	1.098	
2	1	2.502	2.020	3.453	2.189	2.541	
	3	1.816	1.415	2.640	2.264	2.033	
	4	.	1.275	2.642	2.073	1.997	2.168
	5	1.581	2.146	2.650	1.863	2.060	
3	0	2.876	2.935	2.044	5.225	3.270	
	7	.	.	6.056	6.425	6.241	4.105
	8	4.012	3.270	.	.	3.641	
4	9	6.774	7.062	11.152	8.449	8.359	8.359
5	11	0.113	0.100	0.163	0.183	0.140	0.140
.	LOCALITIES	2.470	2.363	3.397	3.307	2.898	
	REGIONS	2.417		3.354			

SUMMARY TABLE OF MEANS (DRY WEIGHT) BY LOCALITY AND SPECIES.

MEAN OF TITANIUM (x 100)

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	157.123	.	213.248	.	185.185	112.266
	6	18.098	61.548	142.831	80.746	75.806	
2	1	134.167	100.379	65.089	133.008	108.161	
	3	154.935	75.393	421.393	227.467	219.797	
	4	.	76.033	281.508	224.097	193.880	142.626
	5	4.668	82.237	79.853	79.157	61.479	
3	0	622.960	644.823	382.443	694.300	586.132	
	7	.	.	837.000	1031.390	934.195	653.979
	8	497.503	521.410	.	.	509.457	
4	9	474.620	503.211	658.393	642.380	569.651	569.651
5	11	142.667	610.000	533.333	306.667	398.167	398.167
.	LOCALITIES	245.193	297.226	361.509	379.912	322.056	
	REGIONS		271.210		370.227		

SUMMARY TABLE OF MEANS (DRY WEIGHT) BY LOCALITY AND SPECIES.

MEAN OF VANADIUM (x 100)

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	79.175	.	46.015	.	62.595	60.397
	6	65.481	51.616	47.501	72.593	59.298	
2	1	105.769	86.655	116.249	98.919	101.898	
	3	75.252	48.469	78.979	65.901	67.150	
	4	.	56.784	75.205	57.165	63.051	75.353
	5	60.485	66.729	71.228	66.509	66.238	
3	0	77.135	62.036	61.901	86.870	71.985	
	7	.	.	98.930	90.443	94.687	75.815
	8	64.071	65.131	.	.	64.601	
4	9	148.037	110.421	225.087	167.223	162.692	162.692
5	11	8.333	18.000	13.667	11.667	12.917	12.917
. LOCALITIES		75.971	62.871	83.476	79.699	75.720	
REGIONS		69.421		81.687			

SUMMARY TABLE OF MEANS (DRY WEIGHT) BY LOCALITY AND SPECIES.

MEAN OF ZINC (x 0.1)

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	6.300	.	5.260	.	5.780	4.613
	6	5.162	3.162	3.621	4.170	4.029	
2	1	2.677	1.614	1.616	2.039	1.987	
	3	1.729	1.488	2.167	2.110	1.873	
	4	.	1.018	1.494	1.783	1.431	1.861
	5	2.279	1.522	2.046	2.330	2.044	
3	0	1.273	0.843	0.998	1.609	1.181	
	7	.	.	2.357	1.974	2.165	1.454
	8	1.421	1.159	.	.	1.290	
4	9	2.806	1.702	4.303	3.270	3.020	3.020
5	11	0.007	0.007	0.020	0.043	0.019	0.019
.	LOCALITIES	2.628	1.390	2.388	2.148	2.145	
	REGIONS	2.009		2.274			

APPENDIX III

Summaries of transfer ratios of non-radioactive elements by locality, region, species and species groups.

Species and species groups codes are as follows:

SPECIES	GROUP = Species Group
0) *Cladina stellaris* (Opiz.) Brodo	3) Lichen
1) *Vaccinium myrtilloides* Michx.	2) Shrub
2) *Pinus banksiana* Lamb.	1) Tree
3) *Ledum groenlandicum* Oeder.	2) Shrub
4) *Alnus crispa* (Ait.) Pursh.	2) Shrub
5) *Vaccinium vitis-idaea* L.	2) Shrub
6) *Picea mariana* (Mill.) BSP	1) Tree
7) *Cladina rangiferina* (L.) Harm.	3) Lichen
8) *C. mitis* (Sandst.) Hale & W. Culb.	3) Lichen
9) *Pleurozium schreberi* (Brid.) Mitt.	4) Moss
11) Soil	5) Soil

SUMMARY TABLE OF MEAN TRANSFER RATIOS FOR PLANT SPECIES (BASED ON DRY WEIGHTS) BY LOCALITY WITH SNK MULTIPLE RANGE TESTS

MEAN OF ALUMINUM

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	0.095	.	0.051	.	0.073	0.029
	6	0.010	0.006	0.010	0.005	0.008	
2	1	0.037	0.021	0.032	0.018	0.027	
	3	0.014	0.008	0.015	0.008	0.011	
	4	.	0.028	0.030	0.013	0.024	0.021
	5	0.027	0.017	0.028	0.012	0.021	
3	0	0.074	0.027	0.035	0.033	0.043	
	7	.	.	0.054	0.029	0.042	0.044
	8	0.062	0.034	.	.	0.048	
4	9	0.067	0.042	0.090	0.046	0.061	0.061
.	LOCALITIES	0.048	0.023	0.038	0.021	0.033	
	REGIONS		0.036		0.030		

SUMMARY TABLE OF MEAN TRANSFER RATIOS FOR PLANT SPECIES (BASED ON DRY WEIGHTS) BY LOCALITY WITH SNK MULTIPLE RANGE TESTS

MEAN OF BERYLL

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	0.022	.	0.013	.	0.017	0.014
	6	0.015	0.013	0.012	0.008	0.012	
2	1	0.006	0.007	0.018	0.008	0.010	
	3	0.019	0.015	0.015	0.012	0.015	
	4	.	0.037	0.064	0.027	0.043	0.017
	5	0.013	0.004	0.006	0.008	0.008	
3	0	0.051	0.026	0.032	0.043	0.038	
	7	.	.	0.051	0.039	0.045	0.036
	8	0.030	0.020	.	.	0.025	
4	9	0.041	0.032	0.069	0.046	0.047	0.047
. LOCALITIES		0.025	0.019	0.031	0.024	0.025	
REGIONS		0.028		0.022			

SUMMARY TABLE OF MEAN TRANSFER RATIOS FOR PLANT SPECIES (BASED ON DRY WEIGHTS) BY LOCALITY WITH SNK MULTIPLE RANGE TESTS

MEAN OF BORON

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	1.857	.	1.355	.	1.606	1.258
	6	1.902	0.857	0.804	0.773	1.084	
2	1	1.987	1.007	1.829	2.368	1.798	
	3	3.037	1.899	2.096	1.843	2.219	
	4	.	1.530	0.856	0.813	1.066	1.671
	5	1.634	1.401	1.036	1.724	1.449	
3	0	0.041	0.032	0.014	0.043	0.032	
	7	.	.	0.053	0.073	0.063	0.052
	8	0.100	0.057	.	.	0.079	
4	9	0.225	0.293	0.194	0.151	0.216	0.216
.	LOCALITIES	1.348	0.884	0.915	0.973	1.027	
	REGIONS		1.116		0.943		

SUMMARY TABLE OF MEAN TRANSFER RATIOS FOR PLANT SPECIES (BASED ON DRY WEIGHTS) BY LOCALITY WITH SNK MULTIPLE RANGE TESTS

MEAN OF CADMIUM

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	0.388	.	0.392	.	0.390	0.160
	6	0.054	0.038	0.045	0.040	0.044	
2	1	0.112	0.044	0.072	0.058	0.071	
	3	0.081	0.046	0.073	0.043	0.061	
	4	.	0.021	0.023	0.061	0.035	0.072
	5	0.075	0.037	0.197	0.136	0.110	
3	0	0.273	0.193	0.385	0.497	0.337	
	7	.	.	0.640	0.462	0.551	0.360
	8	0.211	0.216	.	.	0.213	
4	9	0.485	0.313	0.919	0.528	0.561	0.561
.	LOCALITIES	0.210	0.113	0.305	0.228	0.217	
	REGIONS	0.162		0.269			

SUMMARY TABLE OF MEAN TRANSFER RATIOS FOR PLANT SPECIES (BASED ON DRY WEIGHTS) BY LOCALITY WITH SNK MULTIPLE RANGE TESTS

MEAN OF CALCIUM

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	3.673	.	2.792	.	3.233	3.926
	6	4.920	4.533	3.594	4.045	4.273	
2	1	4.778	4.878	6.641	5.344	5.410	
	3	6.027	6.377	5.809	5.172	5.846	
	4	.	3.567	2.790	4.288	3.548	5.217
	5	5.163	6.961	5.711	4.746	5.645	
3	0	0.352	0.230	0.159	0.334	0.269	
	7	.	.	0.424	0.477	0.450	0.381
	8	0.595	0.478	.	.	0.536	
4	9	2.536	1.911	2.802	2.295	2.386	2.386
. LOCALITIES		3.505	3.617	3.414	3.338	3.467	
REGIONS		3.561		3.378			

SUMMARY TABLE OF MEAN TRANSFER RATIOS FOR PLANT SPECIES (BASED ON DRY WEIGHTS) BY LOCALITY WITH SNK MULTIPLE RANGE TESTS

MEAN OF CHROMIUM

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	0.013	.	0.020	.	0.017	0.012
	6	0.007	0.019	0.006	0.008	0.010	
2	1	0.009	0.025	0.011	0.008	0.013	
	3	0.007	0.019	0.014	0.006	0.012	
	4	.	0.018	0.010	0.011	0.013	0.012
	5	0.006	0.021	0.008	0.007	0.010	
3	0	0.008	0.084	0.012	0.012	0.029	
	7	.	.	0.018	0.013	0.016	0.024
	8	0.008	0.034	.	.	0.021	
4	9	0.013	0.039	0.039	0.015	0.026	0.026
.	LOCALITIES	0.009	0.033	0.015	0.010	0.017	
	REGIONS		0.021		0.013		

SUMMARY TABLE OF MEAN TRANSFER RATIOS FOR PLANT SPECIES (BASED ON DRY WEIGHTS) BY LOCALITY WITH SNK MULTIPLE RANGE TESTS

MEAN OF COBALT

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	0.103	.	0.059	.	0.081	0.047
	6	0.025	0.010	0.051	0.033	0.030	
2	1	0.030	0.023	0.221	0.065	0.085	
	3	0.039	0.011	0.101	0.048	0.050	
	4	.	0.360	1.100	0.728	0.729	0.189
	5	0.018	0.016	0.037	0.043	0.029	
3	0	0.084	0.036	0.091	0.093	0.076	
	7	.	.	0.191	0.103	0.147	0.088
	8	0.069	0.039	.	.	0.054	
4	9	0.134	0.056	0.383	0.176	0.187	0.187
. LOCALITIES		0.063	0.069	0.248	0.161	0.139	
REGIONS		0.066		0.207			

SUMMARY TABLE OF MEAN TRANSFER RATIOS FOR PLANT SPECIES (BASED ON DRY WEIGHTS) BY LOCALITY WITH SNK MULTIPLE RANGE TESTS

MEAN OF COPPER

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	17.627	.	9.034	.	13.331	1.144
	6	21.573	13.583	4.965	1.832	10.488	
2	1	40.219	42.647	19.433	3.715	26.504	
	3	43.434	33.555	12.647	2.808	23.111	
	4	.	34.607	17.756	3.457	18.607	2.248
	5	40.054	30.588	9.611	2.740	20.748	
3	0	6.025	4.823	1.557	0.767	3.293	
	7	.	.	3.176	1.022	2.099	0.348
	8	5.787	4.712	.	.	5.249	
4	9	23.368	21.568	12.178	2.208	14.831	1.483
.	LOCALITIES	24.761	23.260	10.040	2.319	14.942	
	REGIONS		2.401		0.641		

SUMMARY TABLE OF MEAN TRANSFER RATIOS FOR PLANT SPECIES (BASED ON DRY WEIGHTS) BY LOCALITY WITH SNK MULTIPLE RANGE TESTS

MEAN OF IRON

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	0.016	.	0.011	.	0.013	0.008
	6	0.005	0.005	0.007	0.007	0.006	
2	1	0.021	0.015	0.029	0.022	0.022	
	3	0.013	0.006	0.016	0.014	0.012	
	4	.	0.013	0.021	0.016	0.017	0.015
	5	0.007	0.008	0.014	0.010	0.010	
3	0	0.036	0.019	0.031	0.045	0.033	
	7	.	.	0.052	0.034	0.043	0.036
	8	0.039	0.029	.	.	0.034	
4	9	0.055	0.037	0.100	0.081	0.068	0.068
. LOCALITIES		0.024	0.016	0.031	0.029	0.025	
REGIONS		0.020		0.030			

SUMMARY TABLE OF MEAN TRANSFER RATIOS FOR PLANT SPECIES (BASED ON DRY WEIGHTS) BY LOCALITY WITH SNK MULTIPLE RANGE TESTS

MEAN OF LEAD

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	0.023	.	0.029	.	0.026	0.037
	6	0.039	0.067	0.044	0.021	0.043	
2	1	0.016	0.014	0.026	0.014	0.017	
	3	0.049	0.046	0.135	0.082	0.078	
	4	.	0.021	0.013	0.094	0.043	0.039
	5	0.027	0.016	0.013	0.021	0.019	
3	0	0.666	0.482	0.710	0.776	0.658	
	7	.	.	0.714	0.377	0.545	0.526
	8	0.224	0.258	.	.	0.241	
4	9	0.725	0.532	0.679	0.376	0.578	0.578
. LOCALITIES		0.221	0.179	0.262	0.220	0.222	
REGIONS		0.200		0.242			

SUMMARY TABLE OF MEAN TRANSFER RATIOS FOR PLANT SPECIES (BASED ON DRY WEIGHTS) BY LOCALITY WITH SNK MULTIPLE RANGE TESTS

MEAN OF MAGNES

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	1.491	.	2.265	.	1.878	1.859
	6	1.629	1.029	2.799	1.940	1.849	
2	1	2.243	1.894	5.392	3.138	3.167	
	3	2.379	1.038	3.415	2.326	2.289	
	4	.	1.824	4.966	2.975	3.255	2.713
	5	1.951	1.327	3.447	2.378	2.276	
3	0	0.305	0.123	0.292	0.399	0.280	
	7	.	.	0.786	0.543	0.665	0.397
	8	0.482	0.247	.	.	0.364	
4	9	2.079	0.765	2.829	1.793	1.867	1.867
. LOCALITIES		1.570	1.031	2.910	1.937	1.894	
REGIONS		1.300		2.452			

SUMMARY TABLE OF MEAN TRANSFER RATIOS FOR PLANT SPECIES (BASED ON DRY WEIGHTS) BY LOCALITY WITH SNK MULTIPLE RANGE TESTS

MEAN OF MANGAN (x 0.001)

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	1.875	.	0.591	.	1.233	1.508
	6	3.503	1.278	0.412	1.390	1.646	
2	1	11.221	3.313	1.312	4.122	4.992	
	3	1.841	1.376	1.157	1.576	1.488	
	4	.	0.144	0.092	0.374	0.203	2.576
	5	3.041	5.213	1.411	2.455	3.030	
3	0	0.154	0.085	0.019	0.102	0.090	
	7	.	.	0.061	0.169	0.115	0.110
	8	0.154	0.135	.	.	0.144	
4	9	1.246	0.731	0.520	1.056	0.888	0.888
.	LOCALITIES	2.879	1.534	0.619	1.406	1.580	
	REGIONS	2.207		0.989			

SUMMARY TABLE OF MEAN TRANSFER RATIOS FOR PLANT SPECIES (BASED ON DRY WEIGHTS) BY LOCALITY WITH SNK MULTIPLE RANGE TESTS

MEAN OF NICKEL

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	0.222	.	0.480	.	0.351	0.210
	6	0.058	0.108	0.221	0.170	0.139	
2	1	0.125	0.288	0.704	0.152	0.317	
	3	0.152	0.220	0.438	0.108	0.229	
	4	.	0.522	1.231	0.419	0.724	0.319
	5	0.072	0.081	0.147	0.124	0.106	
3	0	0.049	0.163	0.164	0.060	0.109	
	7	.	.	0.354	0.075	0.214	0.129
	8	0.057	0.108	.	.	0.083	
4	9	0.086	0.104	0.378	0.109	0.169	0.169
. LOCALITIES		0.103	0.199	0.457	0.152	0.235	

REGIONS 0.15.098 0.31.367

SUMMARY TABLE OF MEAN TRANSFER RATIOS FOR PLANT SPECIES (BASED ON DRY WEIGHTS) BY LOCALITY WITH SNK MULTIPLE RANGE TESTS

MEAN OF PHOSPHOR

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	7.509	.	3.844	.	5.677	5.549
	6	10.602	5.349	4.096	1.891	5.485	
2	1	8.465	6.646	3.939	1.633	5.171	
	3	6.004	6.971	5.036	1.756	4.942	
	4	.	11.009	7.081	2.043	6.711	5.266
	5	8.144	5.535	3.365	1.365	4.602	
3	0	2.980	1.440	0.795	0.765	1.495	
	7	.	.	3.141	1.110	2.125	2.242
	8	4.933	2.775	.	.	3.854	
4	9	10.139	4.104	5.747	1.961	5.488	5.488
. LOCALITIES		7.347	5.479	4.116	1.565	4.611	

REGIONS 6.413 2.916

SUMMARY TABLE OF MEAN TRANSFER RATIOS FOR PLANT SPECIES (BASED ON DRY WEIGHTS) BY LOCALITY WITH SNK MULTIPLE RANGE TESTS

MEAN OF POTASS

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	3.123	.	2.405	.	2.764	3.142
	6	3.554	4.130	3.215	2.426	3.331	
2	1	0.964	2.096	1.568	0.549	1.294	
	3	4.313	5.119	4.722	2.089	4.061	
	4	.	2.920	2.010	3.361	2.764	2.580
	5	3.441	2.294	1.275	1.985	2.249	
3	0	0.527	0.531	0.513	0.328	0.475	
	7	.	.	0.988	0.444	0.716	0.805
	8	1.685	1.422	.	.	1.554	
4	9	4.178	3.960	4.624	2.944	3.927	3.927
. LOCALITIES		2.723	2.809	2.369	1.766	2.415	

REGIONS 2.766 2.085

SUMMARY TABLE OF MEAN TRANSFER RATIOS FOR PLANT SPECIES (BASED ON DRY WEIGHTS) BY LOCALITY WITH SNK MULTIPLE RANGE TESTS

MEAN OF SILVER

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	0.233	.	0.118	.	0.176	0.148
	6	0.232	0.071	0.146	0.086	0.134	
2	1	0.998	0.112	0.206	0.337	0.413	
	3	0.165	0.076	0.193	0.177	0.153	
	4	.	0.017	0.011	0.085	0.038	0.232
	5	0.315	0.284	0.238	0.263	0.275	
3	0	0.008	0.003	0.004	0.004	0.004	
	7	.	.	0.005	0.009	0.007	0.009
	8	0.023	0.017	.	.	0.020	
4	9	0.038	0.042	0.031	0.026	0.034	0.034
.	LOCALITIES	0.251	0.078	0.106	0.123	0.139	
	REGIONS		0.165		0.114		

SUMMARY TABLE OF MEAN TRANSFER RATIOS FOR PLANT SPECIES (BASED ON DRY WEIGHTS) BY LOCALITY WITH SNK MULTIPLE RANGE TESTS

MEAN OF SODIUM

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	0.136	.	0.127	.	0.132	0.101
	6	0.093	0.105	0.080	0.063	0.086	
2	1	0.221	0.203	0.214	0.123	0.190	
	3	0.164	0.143	0.170	0.131	0.152	
	4	.	0.128	0.172	0.118	0.140	0.161
	5	0.140	0.207	0.168	0.107	0.155	
3	0	0.255	0.307	0.129	0.304	0.249	
	7	.	.	0.384	0.376	0.380	0.306
	8	0.360	0.329	.	.	0.345	
4	9	0.602	0.708	0.707	0.494	0.628	0.628
.	LOCALITIES	0.247	0.266	0.239	0.215	0.242	
	REGIONS	0.256		0.228			

SUMMARY TABLE OF MEAN TRANSFER RATIOS FOR PLANT SPECIES (BASED ON DRY WEIGHTS) BY LOCALITY WITH SNK MULTIPLE RANGE TESTS

MEAN OF TITANIUM

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	0.014	.	0.007	.	0.011	0.005
	6	0.001	0.001	0.005	0.003	0.002	
2	1	0.013	0.002	0.002	0.004	0.005	
	3	0.013	0.001	0.014	0.008	0.009	
	4	.	0.001	0.012	0.008	0.007	0.006
	5	0.000	0.001	0.002	0.002	0.002	
3	0	0.060	0.011	0.012	0.026	0.027	
	7	.	.	0.025	0.035	0.030	0.028
	8	0.046	0.009	.	.	0.027	
4	9	0.038	0.008	0.025	0.022	0.023	0.023
. LOCALITIES		0.023	0.004	0.012	0.013	0.013	
REGIONS		0.014		0.012			

SUMMARY TABLE OF MEAN TRANSFER RATIOS FOR PLANT SPECIES (BASED ON DRY WEIGHTS) BY LOCALITY WITH SNK MULTIPLE RANGE TESTS

MEAN OF VANADIUM

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	0.109	.	0.051	.	0.080	0.067
	6	0.091	0.030	0.055	0.064	0.060	
2	1	0.139	0.052	0.146	0.090	0.107	
	3	0.097	0.029	0.088	0.058	0.068	
	4	.	0.035	0.091	0.050	0.059	0.076
	5	0.083	0.044	0.081	0.059	0.067	
3	0	0.109	0.039	0.072	0.077	0.074	
	7	.	.	0.123	0.080	0.101	0.078
	8	0.090	0.040	.	.	0.065	
4	9	0.204	0.068	0.272	0.144	0.172	0.172
. LOCALITIES		0.115	0.042	0.109	0.078	0.087	

REGIONS 0.079 0.094

SUMMARY TABLE OF MEAN TRANSFER RATIOS FOR PLANT SPECIES (BASED ON DRY WEIGHTS) BY LOCALITY WITH SNK MULTIPLE RANGE TESTS

MEAN OF ZINC

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	99.044	.	2.630	.	50.837	40.16
	6	89.883	46.556	1.811	1.035	34.821	
2	1	41.258	28.531	0.808	0.519	17.779	
	3	20.642	27.268	1.083	0.544	12.384	
	4	.	20.389	0.747	0.482	7.206	14.59
	5	41.612	33.389	1.023	0.582	19.151	
3	0	26.906	11.948	0.499	0.401	9.938	
	7	.	.	1.178	0.489	0.834	9.89
	8	18.244	19.467	.	.	18.856	
4	9	37.752	31.282	2.151	0.865	18.013	18.01
.	LOCALITIES	46.918	27.354	1.326	0.615	18.516	
	REGIONS	37.136		.996			

APPENDIX IV

Summaries of enrichment factors of non-radioactive elements by locality, region, species and species groups.

Species and species group codes are as follows:

SPECIES	GROUP = Species Group
0) *Cladina stellaris* (Opiz.) Brodo	3) Lichen
1) *Vaccinium myrtilloides* Michx.	2) Shrub
2) *Pinus banksiana* Lamb.	1) Tree
3) *Ledum groenlandicum* Oeder.	2) Shrub
4) *Alnus crispa* (Ait.) Pursh.	2) Shrub
5) *Vaccinium vitis-idaea* L.	2) Shrub
6) *Picea mariana* (Mill.) BSP	1) Tree
7) *Cladina rangiferina* (L.) Harm.	3) Lichen
8) *C. mitis* (Sandst.) Hale & W. Culb.	3) Lichen
9) *Pleurozium schreberi* (Brid.) Mitt.	4) Moss
11) Soil	5) Soil

SUMMARY TABLE OF MEAN ENRICHMENT FACTORS FOR SPECIES
BY LOCALITY WITH SNK MULTIPLE RANGE TESTS.

MEAN OF ALUMINUM

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	7.538	.	7.444	.	7.491	9.113
	6	28.763	6.200	2.652	2.079	9.924	
2	1	3.987	23.034	16.473	5.124	12.155	
	3	1.046	7.063	1.145	1.112	2.592	
	4	.	24.571	8.055	1.756	11.461	14.035
	5	86.824	12.599	12.093	5.634	29.288	
3	0	1.283	2.557	4.236	1.907	2.496	
	7	.	.	2.177	0.848	1.513	2.296
	8	1.378	3.980	.	.	2.679	
4	9	1.685	15.002	4.293	2.296	5.819	5.819
. LOCALITIES		16.563	11.876	6.508	2.595	9.298	
REGIONS		14.219		4.666			

SUMMARY TABLE OF MEAN ENRICHMENT FACTORS FOR SPECIES
BY LOCALITY WITH SNK MULTIPLE RANGE TESTS.

MEAN OF BERYLL

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	1.913	.	2.246	.	2.079	10.539
	6	37.714	12.886	5.020	3.456	14.769	
2	1	0.632	7.290	9.969	2.220	5.028	
	3	1.410	13.226	1.695	1.509	4.460	
	4	.	32.642	19.703	3.675	18.673	10.081
	5	47.578	3.026	2.608	4.027	14.310	
3	0	0.944	2.435	4.999	2.483	2.715	
	7	.	.	2.345	1.150	1.748	2.170
	8	0.673	2.333	.	.	1.503	
4	9	1.053	12.258	4.228	2.223	4.940	4.940
. LOCALITIES		11.490	10.762	5.868	2.593	7.623	

REGIONS 11.126 4.327

SUMMARY TABLE OF MEAN ENRICHMENT FACTORS FOR SPECIES
BY LOCALITY WITH SNK MULTIPLE RANGE TESTS.

MEAN OF BORON (x 0.1)

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	17.948	.	34.556	.	26.252	109.50
	6	440.763	84.550	46.645	32.535	151.123	
2	1	29.572	107.127	127.333	66.599	82.658	
	3	27.310	154.797	29.616	24.951	59.168	
	4	.	156.096	38.780	11.278	68.718	128.58
	5	890.000	113.823	70.677	80.667	288.792	
3	0	0.110	0.325	0.345	0.229	0.252	
	7	.	.	0.368	0.215	0.292	0.33
	8	0.364	0.664	.	.	0.514	
4	9	0.632	7.076	1.568	0.789	2.516	2.52
. LOCALITIES		175.837	78.057	38.876	27.158	78.737	
REGIONS		126.95		33.36			

SUMMARY TABLE OF MEAN ENRICHMENT FACTORS FOR SPECIES
BY LOCALITY WITH SNK MULTIPLE RANGE TESTS.

MEAN OF CADMIUM

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	36.746	.	101.968	.	69.357	54.16
	6	111.630	37.080	21.737	15.803	46.562	
2	1	18.745	56.998	41.444	14.456	32.911	
	3	5.580	38.964	11.530	5.750	15.456	
	4	.	33.628	8.023	8.351	16.667	50.72
	5	314.533	25.851	115.775	61.201	129.340	
3	0	6.850	19.238	86.266	31.388	35.935	
	7	.	.	38.140	13.734	25.937	28.44
	8	6.765	25.106	.	.	15.936	
4	9	12.950	91.141	93.445	26.172	55.927	55.93
.	LOCALITIES	64.225	41.001	57.592	22.107	46.575	

REGIONS 52.61 40.89

SUMMARY TABLE OF MEAN ENRICHMENT FACTORS FOR SPECIES
BY LOCALITY WITH SNK MULTIPLE RANGE TESTS.

MEAN OF CALCIUM (x 0.1)

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	2.609	.	0.470	.	1.540	121.54
	6	149.630	445.303	1.051	130.153	181.534	
2	1	3.673	608.545	5.388	77.159	173.691	
	3	3.774	516.062	0.512	54.767	143.779	
	4	.	417.294	0.363	42.830	153.496	165.22
	5	115.151	520.518	3.788	108.452	186.977	
3	0	0.048	2.202	0.022	1.566	0.960	
	7	.	.	0.026	0.906	0.466	1.31
	8	0.106	5.602	.	.	2.854	
4	9	0.521	54.874	0.146	9.076	16.154	16.15
.	LOCALITIES	34.439	321.300	1.307	53.114	99.472	
	REGIONS	177.87		25.69			

SUMMARY TABLE OF MEAN ENRICHMENT FACTORS FOR SPECIES
BY LOCALITY WITH SNK MULTIPLE RANGE TESTS.

MEAN OF CHROMIUM

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	1.369	.	5.424	.	3.396	7.866
	6	13.412	19.335	4.272	3.386	10.101	
2	1	1.577	27.637	8.699	2.085	9.999	
	3	0.696	15.861	2.334	0.978	4.967	
	4	.	18.091	5.784	1.554	8.476	9.540
	5	32.225	16.667	5.516	3.392	14.450	
3	0	0.219	5.667	3.630	0.807	2.581	
	7	.	.	1.434	0.383	0.908	2.051
	8	0.283	3.986	.	.	2.135	
4	9	0.363	9.815	4.253	0.801	3.808	3.808
.	LOCALITIES	6.268	14.632	4.594	1.673	6.725	
	REGIONS	10.450		3.220			

SUMMARY TABLE OF MEAN ENRICHMENT FACTORS FOR SPECIES
BY LOCALITY WITH SNK MULTIPLE RANGE TESTS.

MEAN OF COBALT

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	8.458	.	8.292	.	8.375	20.51
	6	69.376	9.370	13.923	13.650	26.580	
2	1	2.769	30.647	110.072	17.616	40.276	
	3	2.641	9.215	9.522	6.984	7.091	
	4	.	410.068	88.282	100.721	199.691	60.63
	5	72.857	11.312	16.214	20.483	30.217	
3	0	1.590	3.048	9.377	4.702	4.679	
	7	.	.	7.317	2.922	5.119	4.39
	8	1.632	4.515	.	.	3.074	
4	9	3.171	14.395	17.257	8.717	10.885	10.89
. LOCALITIES		20.312	61.571	31.140	21.974	33.670	
REGIONS		40.94		26.83			

SUMMARY TABLE OF MEAN ENRICHMENT FACTORS FOR SPECIES
BY LOCALITY WITH SNK MULTIPLE RANGE TESTS.

MEAN OF COPPER (x 0.001)

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	1.978	.	1.368	.	1.673	10.89
	6	47.093	13.072	0.964	0.878	15.502	
2	1	6.621	53.212	9.771	1.019	17.656	
	3	3.881	26.431	0.801	0.372	7.872	
	4	.	48.371	2.295	0.436	17.034	28.57
	5	246.067	24.468	3.515	1.258	68.827	
3	0	0.177	0.445	0.137	0.039	0.199	
	7	.	.	0.112	0.029	0.070	0.21
	8	0.193	0.550	.	.	0.372	
4	9	0.691	4.747	0.412	0.118	1.492	1.49
.	LOCALITIES	38.338	21.412	2.153	0.519	15.198	
	REGIONS	29.87		1.38			

SUMMARY TABLE OF MEAN ENRICHMENT FACTORS FOR SPECIES
BY LOCALITY WITH SNK MULTIPLE RANGE TESTS.

MEAN OF IRON

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	1.396	.	2.035	.	1.716	4.508
	6	13.292	5.100	2.467	2.757	5.904	
2	1	2.113	14.435	17.170	6.440	10.040	
	3	1.038	5.443	1.552	2.047	2.520	
	4	.	9.345	8.396	2.209	6.650	7.417
	5	24.046	5.608	6.858	4.554	10.267	
3	0	0.626	1.729	4.879	2.584	2.454	
	7	.	.	2.560	1.000	1.780	2.206
	8	0.922	3.352	.	.	2.137	
4	9	1.408	13.752	6.255	3.947	6.340	6.340
.	LOCALITIES	5.605	7.346	5.797	3.192	5.494	
	REGIONS	6.475		4.571			

SUMMARY TABLE OF MEAN ENRICHMENT FACTORS FOR SPECIES
BY LOCALITY WITH SNK MULTIPLE RANGE TESTS.

MEAN OF LEAD

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	2.220	.	6.186	.	4.203	30.68
	6	81.593	69.179	16.749	8.148	43.917	
2	1	2.237	17.071	13.843	4.037	9.297	
	3	3.751	38.964	17.396	10.279	17.597	
	4	.	30.368	6.429	13.270	16.689	20.86
	5	125.333	12.362	7.144	10.414	38.813	
3	0	15.808	48.522	109.432	51.072	56.208	
	7	.	.	36.181	11.276	23.728	38.69
	8	7.777	29.446	.	.	18.612	
4	9	19.078	65.982	34.691	22.962	35.678	35.68
.	LOCALITIES	32.225	38.987	27.561	16.432	28.764	

REGIONS 35.606 22.324

SUMMARY TABLE OF MEAN ENRICHMENT FACTORS FOR SPECIES
BY LOCALITY WITH SNK MULTIPLE RANGE TESTS.

MEAN OF MAGNES (x 0.1)

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	10.276	.	36.421	.	23.348	132.67
	6	472.588	104.804	89.380	82.533	187.326	
2	1	25.197	206.937	304.722	94.677	157.883	
	3	17.560	90.343	29.955	33.407	42.816	
	4	.	183.819	155.696	40.267	126.594	141.20
	5	566.310	101.254	152.840	114.959	233.841	
3	0	0.560	1.250	4.013	2.160	1.996	
	7	.	.	3.472	1.559	2.516	2.14
	8	1.187	2.911	.	.	2.049	
4	9	4.968	30.008	15.307	9.013	14.824	14.82
.	LOCALITIES	137.331	90.166	87.978	47.322	90.617	
	REGIONS		113.75		68.85		

SUMMARY TABLE OF MEAN ENRICHMENT FACTORS FOR SPECIES
BY LOCALITY WITH SNK MULTIPLE RANGE TESTS.

MEAN OF MANGAN (x 0.1)

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	28.316	.	21.083	.	24.699	184.5
	6	942.547	0.071	22.889	92.221	264.432	
2	1	51.923	0.181	173.842	96.661	80.652	
	3	14.029	0.061	23.008	15.605	13.176	
	4	.	0.006	1.987	4.399	2.130	143.5
	5	1559.109	0.213	115.205	96.306	442.708	
3	0	0.280	0.000	0.232	0.375	0.222	
	7	.	.	0.538	0.539	0.539	0.3
	8	0.481	0.001	.	.	0.241	
4	9	2.747	0.012	5.125	5.384	3.317	3.3
. LOCALITIES		324.929	0.068	40.434	38.936	99.254	
REGIONS		162.5		39.7			

SUMMARY TABLE OF MEAN ENRICHMENT FACTORS FOR SPECIES
BY LOCALITY WITH SNK MULTIPLE RANGE TESTS.

MEAN OF NICKEL

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	17.393	.	81.258	.	49.326	84.40
	6	143.947	104.900	76.030	82.893	101.942	
2	1	15.484	343.717	416.620	46.258	205.520	
	3	10.590	168.727	33.889	19.431	58.159	
	4	.	616.235	384.849	59.176	353.420	164.70
	5	162.422	65.202	68.213	59.664	88.875	
3	0	1.028	11.374	33.837	4.545	12.696	
	7	.	.	13.717	2.318	8.018	10.10
	8	1.873	12.097	.	.	6.985	
4	9	2.192	25.612	21.947	5.762	13.878	13.88
. LOCALITIES		44.366	168.483	125.596	35.006	94.339	

REGIONS 106.42 82.97

SUMMARY TABLE OF MEAN ENRICHMENT FACTORS FOR SPECIES
BY LOCALITY WITH SNK MULTIPLE RANGE TESTS.

MEAN OF PHOSPHOR (0.01)

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	6.635	.	4.243	.	5.439	64.34
	6	307.646	50.839	9.083	7.614	93.796	
2	1	9.680	55.895	19.209	5.050	22.458	
	3	5.648	55.293	3.276	2.427	16.661	
	4	.	152.862	10.898	2.737	55.499	47.50
	5	330.723	38.972	13.021	6.800	97.379	
3	0	0.670	1.117	0.825	0.396	0.752	
	7	.	.	1.156	0.322	0.739	1.11
	8	1.329	3.031	.	.	2.180	
4	9	2.673	11.502	2.187	0.941	4.326	4.33
.	LOCALITIES	83.126	46.189	7.100	3.286	34.082	

REGIONS 64.66 5.30

SUMMARY TABLE OF MEAN ENRICHMENT FACTORS FOR SPECIES
BY LOCALITY WITH SNK MULTIPLE RANGE TESTS.

MEAN OF POTASS (x 0.01)

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	3.049	.	5.485	.	4.267	22.94
	6	76.973	25.758	16.713	9.659	32.275	
2	1	1.433	24.395	6.881	1.767	8.619	
	3	3.626	24.341	5.700	2.345	9.003	
	4	.	26.080	8.887	4.586	13.184	19.54
	5	151.440	12.069	8.169	11.435	45.779	
3	0	0.134	0.401	0.937	0.185	0.414	
	7	.	.	0.436	0.129	0.283	0.49
	8	0.568	1.105	.	.	0.836	
4	9	1.207	2.620	4.146	1.250	2.306	2.31
.	LOCALITIES	29.804	14.596	6.373	3.919	13.452	
	REGIONS	22.200		5.218			

SUMMARY TABLE OF MEAN ENRICHMENT FACTORS FOR SPECIES
BY LOCALITY WITH SNK MULTIPLE RANGE TESTS.

MEAN OF SILVER

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	20.950	.	30.201	.	25.575	115.0
	6	472.370	70.438	58.133	37.741	159.671	
2	1	159.044	189.257	136.444	88.237	143.246	
	3	14.435	64.172	27.833	24.306	32.687	
	4	.	18.247	7.471	11.843	12.520	199.0
	5	1742.267	217.118	154.893	129.904	561.046	
3	0	0.287	0.258	1.057	0.238	0.460	
	7	.	.	0.331	0.267	0.299	0.6
	8	0.705	1.925	.	.	1.315	
4	9	0.996	8.821	2.772	1.331	3.480	3.5
. LOCALITIES		301.382	71.280	46.571	36.733	111.948	

REGIONS 186.33 41.94

SUMMARY TABLE OF MEAN ENRICHMENT FACTORS FOR SPECIES
BY LOCALITY WITH SNK MULTIPLE RANGE TESTS.

MEAN OF SODIUM

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	13.669	.	30.837	.	22.253	69.54
	6	200.404	103.163	43.852	25.321	93.185	
2	1	30.091	265.839	149.295	38.305	120.882	
	3	15.864	114.081	21.384	18.575	42.476	
	4	.	153.326	84.644	15.482	84.484	126.27
	5	659.121	166.226	105.322	56.469	246.785	
3	0	7.051	25.487	31 437	15.286	19.815	
	7	.	.	26.341	10.854	18.598	20.76
	8	11.508	38.134	.	.	24.821	
4	9	17.304	187.252	59.772	22.797	71.781	71.78
. LOCALITIES		119.376	131.688	61.432	25.386	83.773	

REGIONS 125.53 44.47

SUMMARY TABLE OF MEAN ENRICHMENT FACTORS FOR SPECIES
BY LOCALITY WITH SNK MULTIPLE RANGE TESTS.

MEAN OF TITANIUM

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	1.000	.	1.000	.	1.000	1.000
	6	1.000	1.000	1.000	1.000	1.000	
2	1	1.000	1.000	1.000	1.000	1.000	
	3	1.000	1.000	1.000	1.000	1.000	
	4	.	1.000	1.000	1.000	1.000	1.000
	5	1.000	1.000	1.000	1.000	1.000	
3	0	1.000	1.000	1.000	1.000	1.000	
	7	.	.	1.000	1.000	1.000	1.000
	8	1.000	1.000	.	.	1.000	
4	9	1.000	1.000	1.000	1.000	1.000	1.000
.	LOCALITIES	1.000	1.000	1.000	1.000	1.000	
	REGIONS		1.000		1.000		

SUMMARY TABLE OF MEAN ENRICHMENT FACTORS FOR SPECIES
BY LOCALITY WITH SNK MULTIPLE RANGE TESTS.

MEAN OF VANADIUM

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	9.664	.	7.715	.	8.689	61.81
	6	280.946	29.877	14.463	28.176	88.365	
2	1	15.594	46.933	74.506	24.594	40.407	
	3	8.012	23.939	6.835	7.926	11.678	
	4	.	36.667	20.158	6.684	21.170	45.37
	5	315.214	31.513	35.023	26.899	102.162	
3	0	2.077	3.473	8.267	4.254	4.518	
	7	.	.	4.821	2.294	3.557	3.99
	8	2.133	4.569	.	.	3.351	
4	9	5.263	22.222	12.922	7.121	11.882	11.88
.	LOCALITIES	79.863	24.899	20.523	13.493	34.265	
	REGIONS		52.38		17.22		

SUMMARY TABLE OF MEAN ENRICHMENT FACTORS FOR SPECIES
BY LOCALITY WITH SNK MULTIPLE RANGE TESTS.

MEAN OF ZINC (x 0.1)

		WOLLASTON LAKE		CHURCHILL RIVER			
		HIDDEN BAY	COLLINS CREEK	BIRCH HILLS	OTTER RAPIDS	SPECIES	GROUPS
GROUP	SPECIES						
1	2	55.632	.	70.433	.	63.033	208.94
	6	784.231	213.990	87.257	42.072	281.887	
2	1	31.226	130.418	58.736	16.795	59.294	
	3	13.981	70.958	13.836	6.951	26.431	
	4	.	90.798	41.413	6.318	46.176	112.85
	5	1045.115	72.915	62.352	31.013	302.849	
3	0	2.448	5.067	11.489	1.962	5.241	
	7	.	.	7.139	1.392	4.266	5.30
	8	3.881	9.040	.	.	6.461	
4	9	7.010	13.218	20.931	3.699	11.215	11.21
* LOCALITIES		242.941	75.800	41.510	13.775	91.931	
REGIONS		159.37		28.46			